JUNE 1960
Volume 195 Part 2

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Incorporated by Royal Charter 1899

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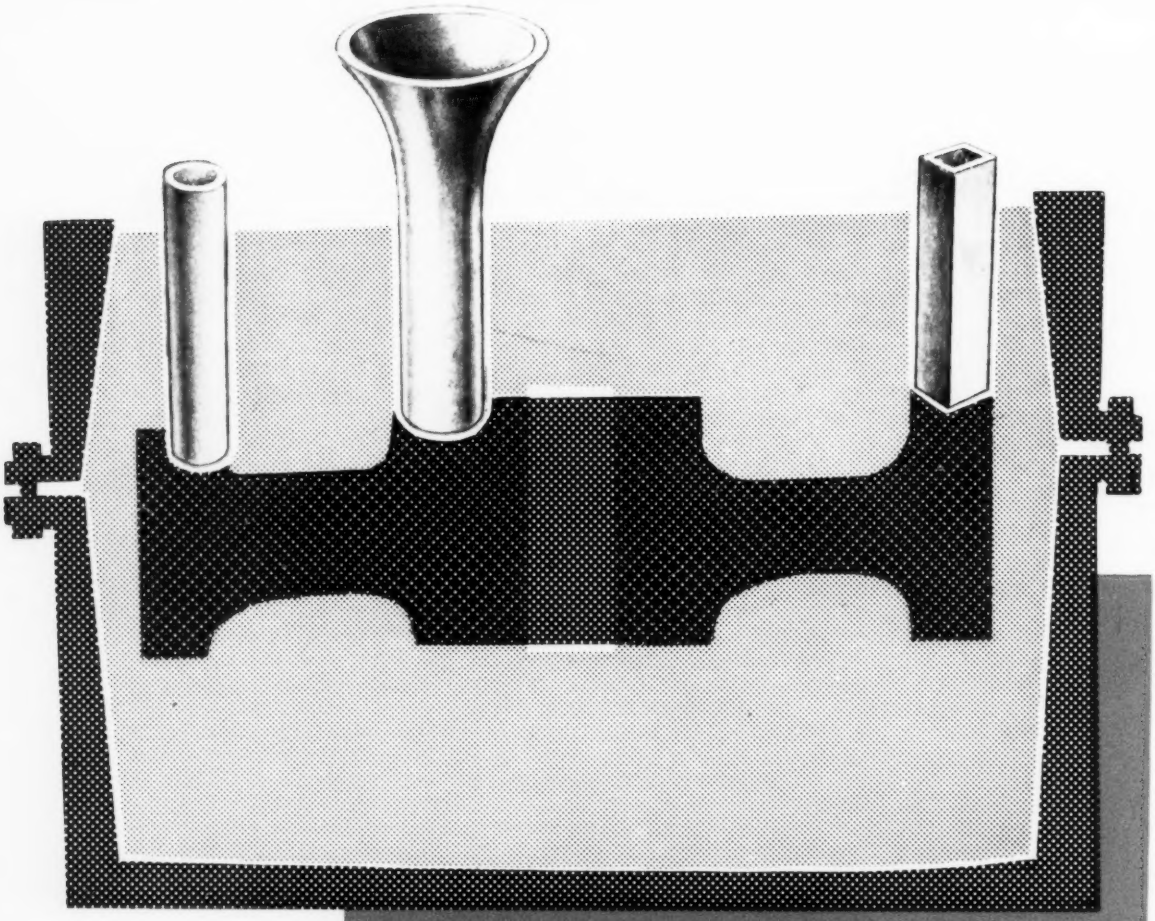

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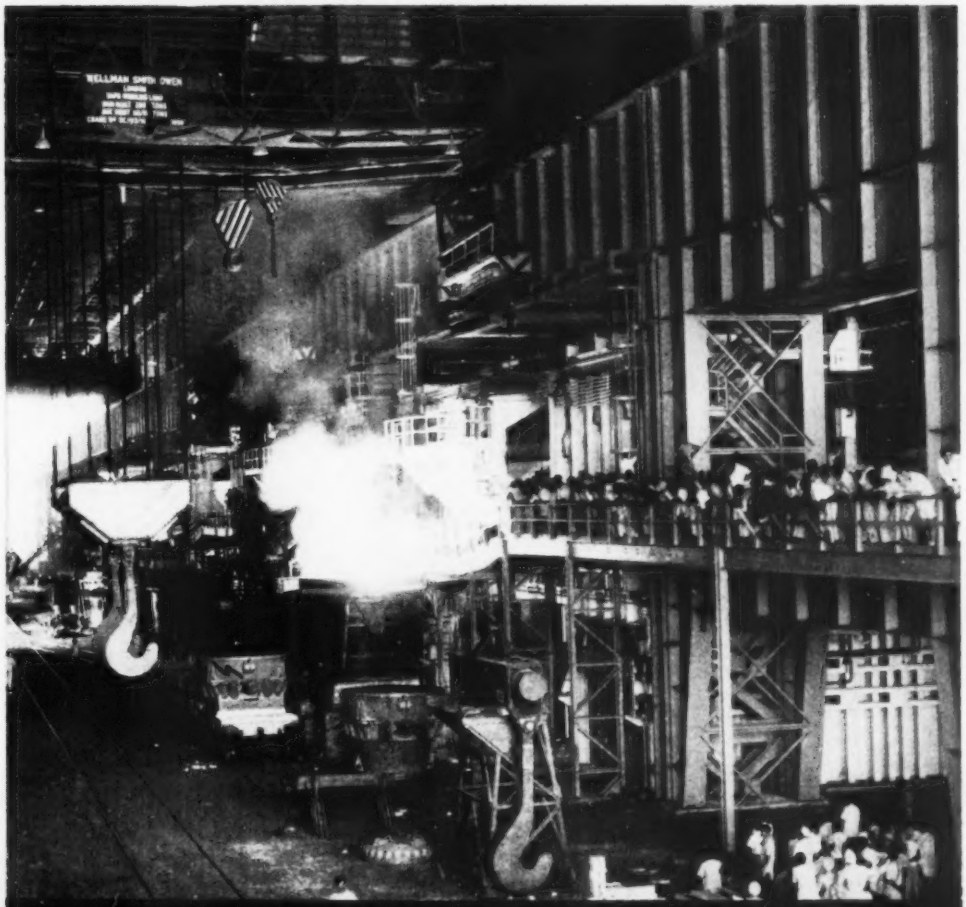

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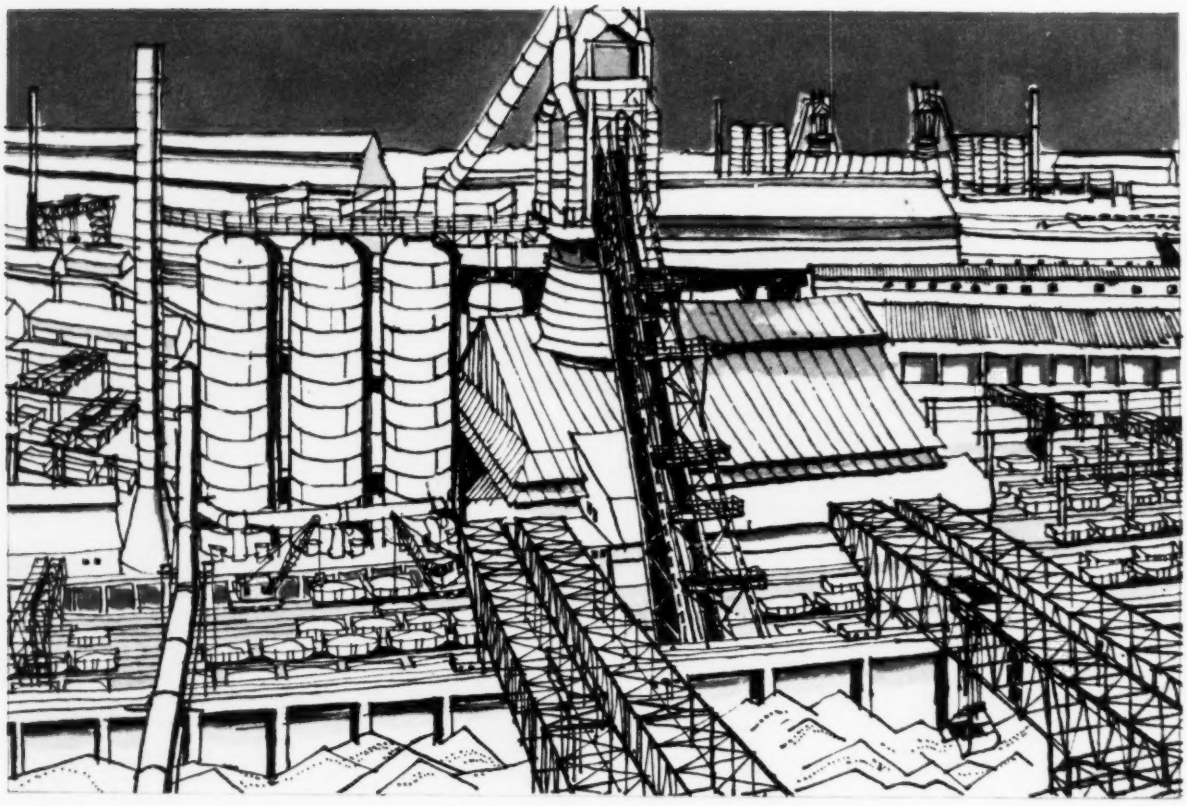

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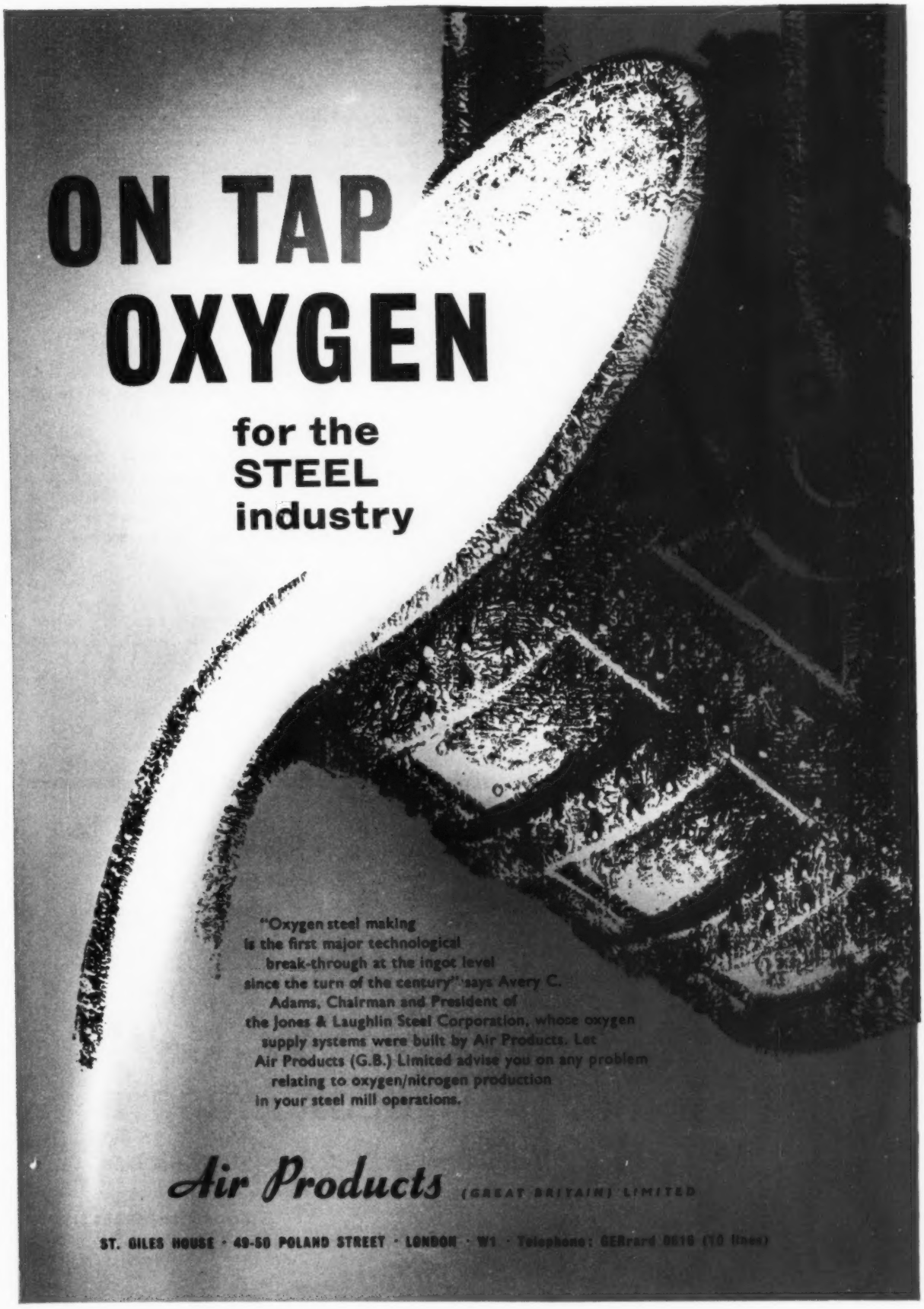
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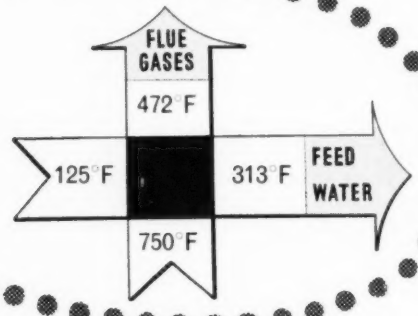

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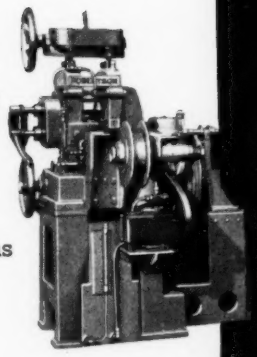
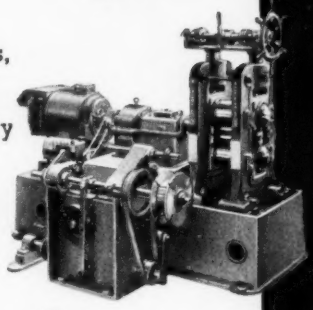
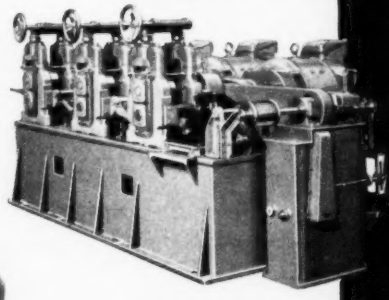


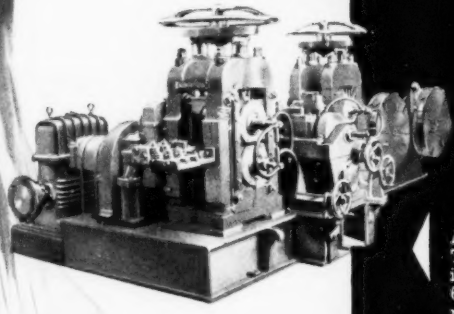
A small Two-High Mill with rolls 4" diameter, 3" face.



A Four-High Single Stand Mill with work rolls 2¼" diameter, 4" face, and support rolls 6¼" diameter, 4" face.

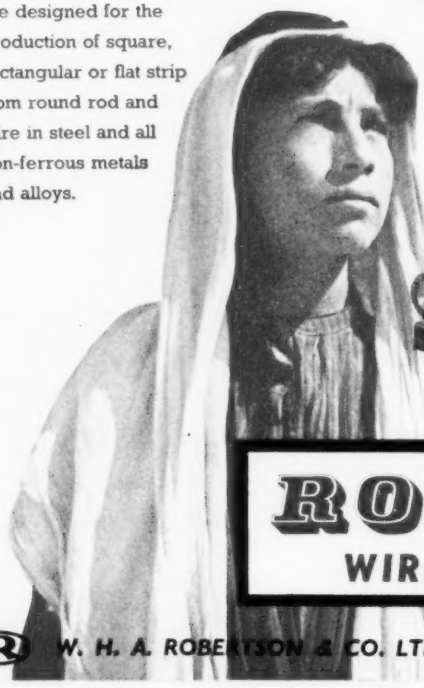


A Three-Stand Tandem, each stand individually motor driven and having rolls 6¼" diameter, 4" face.



A No. 2 Tormanco Tandem, with roughing rolls 10" diameter, 6" face, and finishing rolls 8" diameter, 6" face

The examples illustrated are from the range of Robertson Mills, which are designed for the production of square, rectangular or flat strip from round rod and wire in steel and all non-ferrous metals and alloys.



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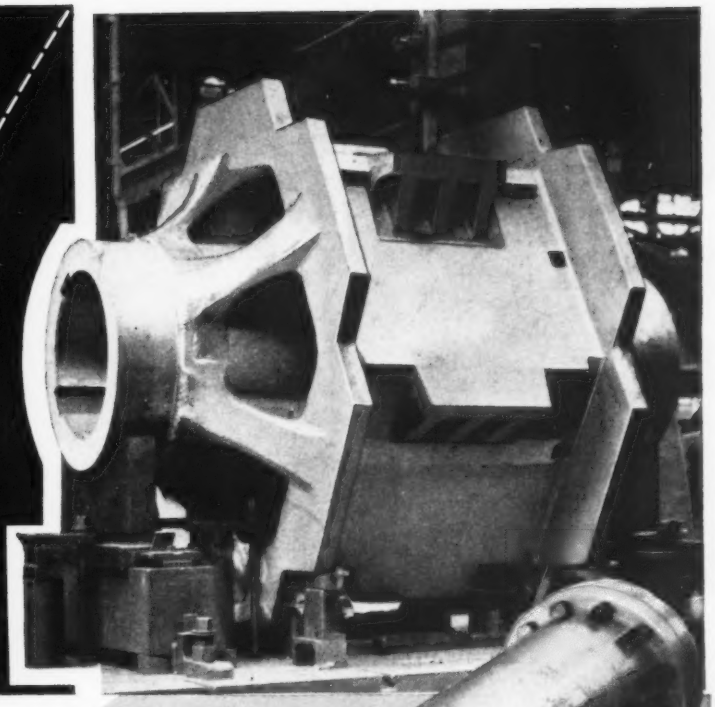

Top tumbler for tin dredging. Weight 17½ tons.

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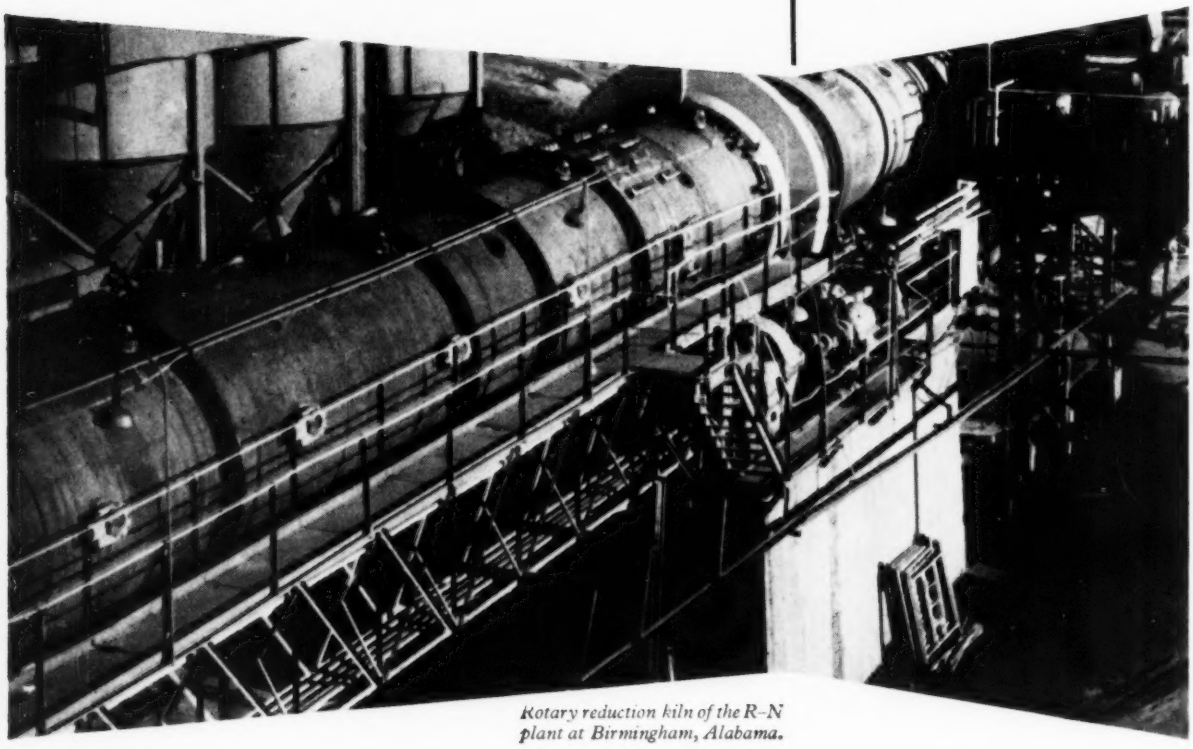

Rotary reduction kiln of the R-N plant at Birmingham, Alabama.

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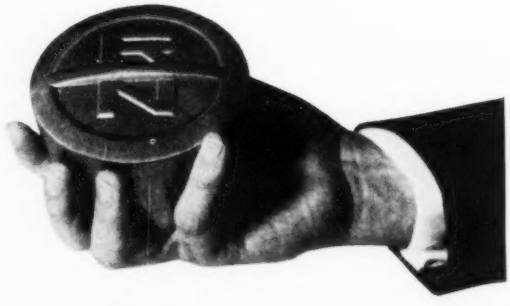

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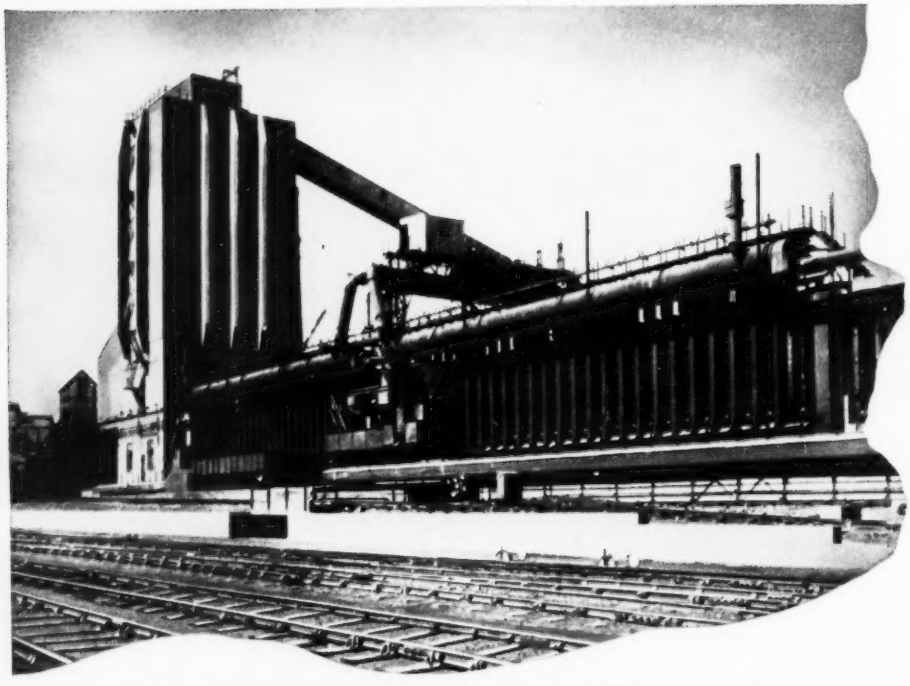

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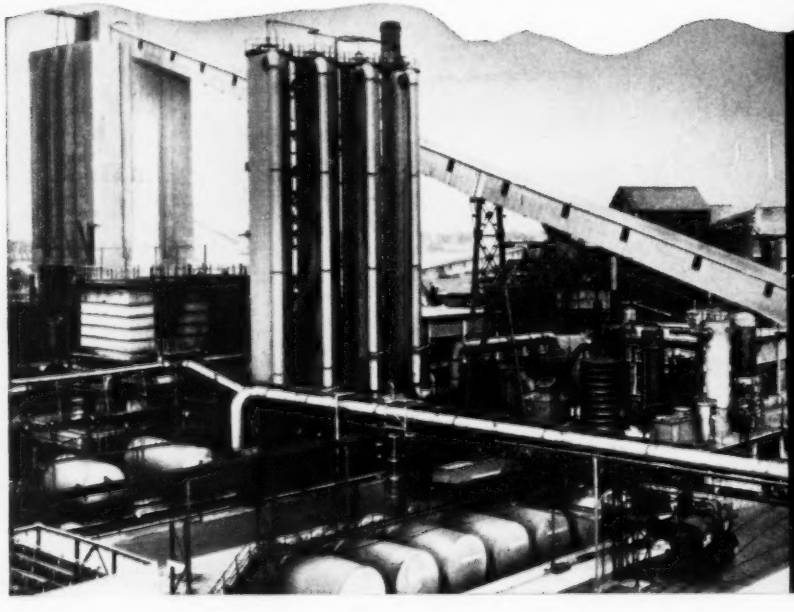

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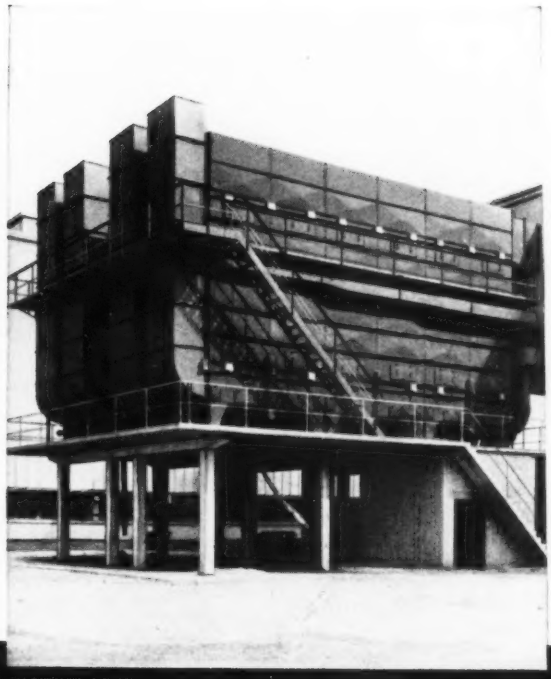

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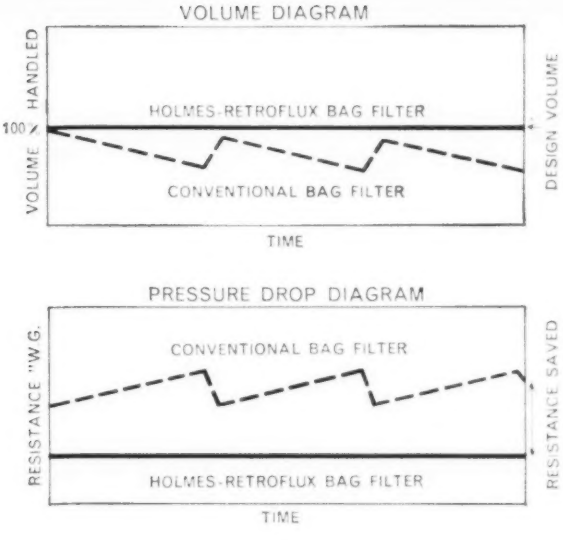

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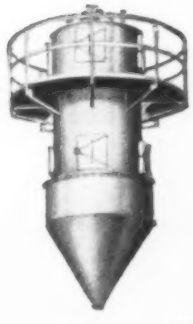

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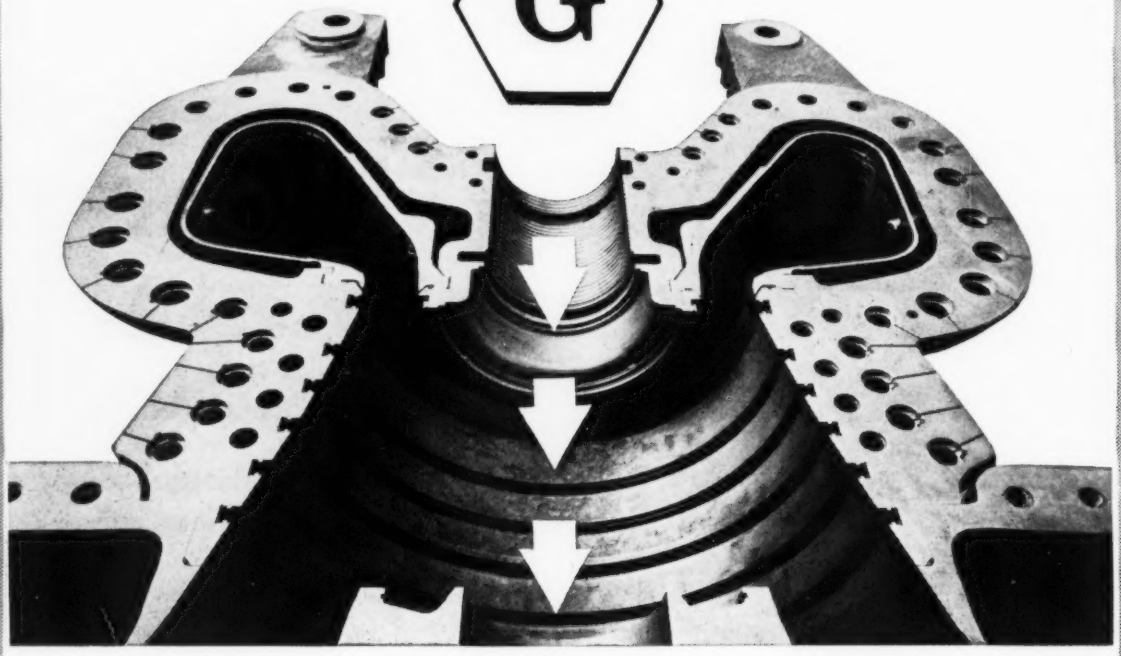

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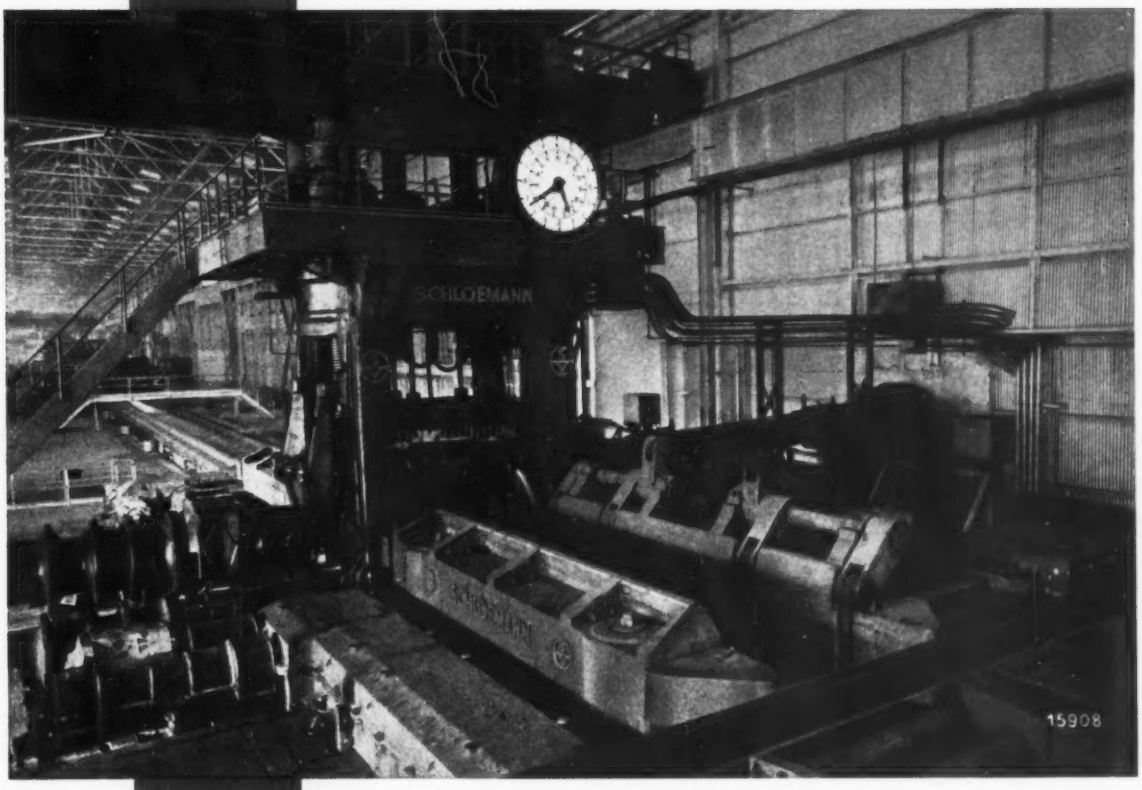

46" blooming and slabbing mill, for piece weights up to 15 tons, built for the Tata Iron and Steel Co. Ltd., Jamshedpur, India.

13 Blooming and Slabbing Mills

During the past seven years SCHLOEMANN have built thirteen blooming and slabbing mills complete with auxiliary equipment. Additionally, extensive equipment has been supplied to modernize existing mills. In all cases particular attention has been paid to robust design, good accessibility and easy interchangeability of the rolls and all wearing parts, an advantage that is much appreciated where semi-skilled labour has to be depended upon.

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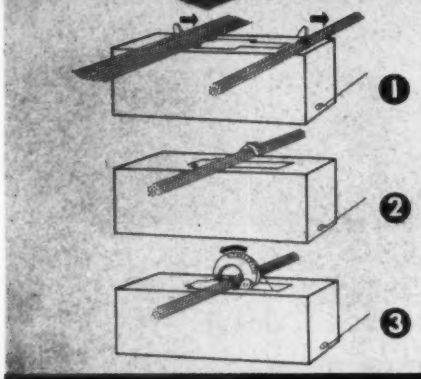

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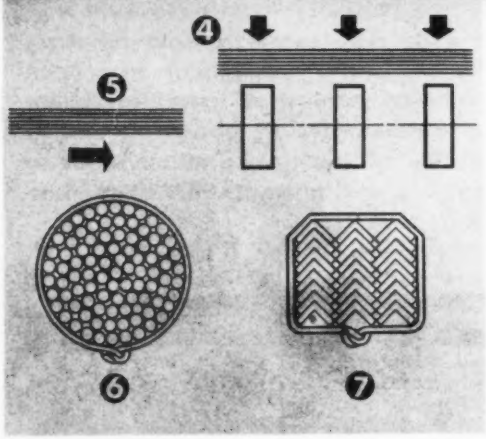

- **be fed laterally as well as longitudinally (figures 4 and 5)**
- **bundle bars in bulk or stacked steel sections (figures 6 and 7)**
- **work at a speed of up to 1000 ties an hour**

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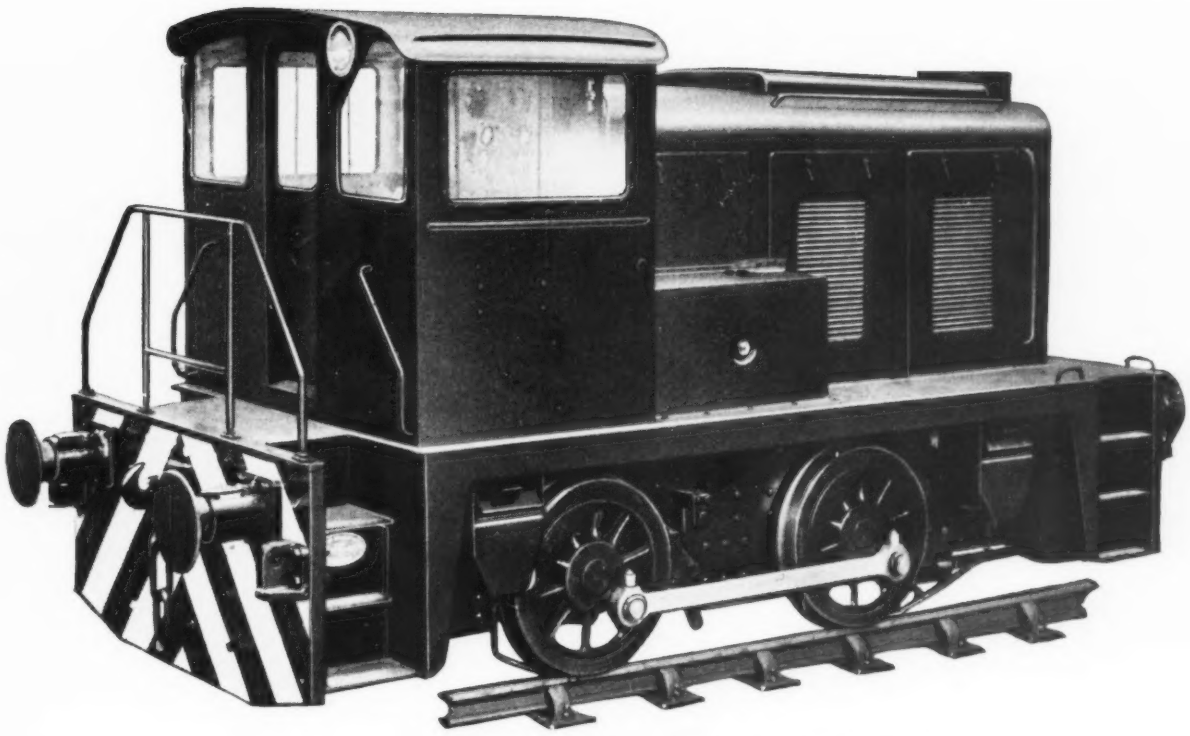
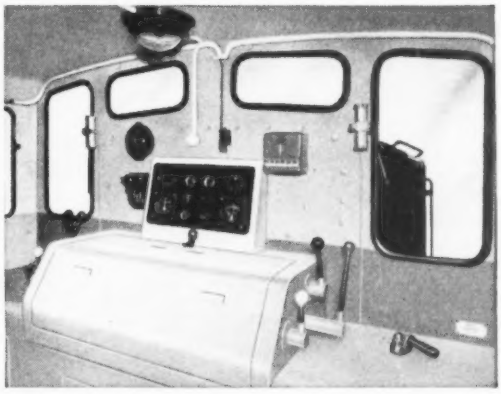


YORKSHIRE 170 H.P. diesel-hydraulic locomotive

This YORKSHIRE diesel-hydraulic shunting locomotive is powered by a ROLLS-ROYCE oil engine and a ROLLS-ROYCE twin-disc torque converter drives direct to an axle-hung, double reduction reversing gearbox. The controls are extremely simple and speedy to operate.



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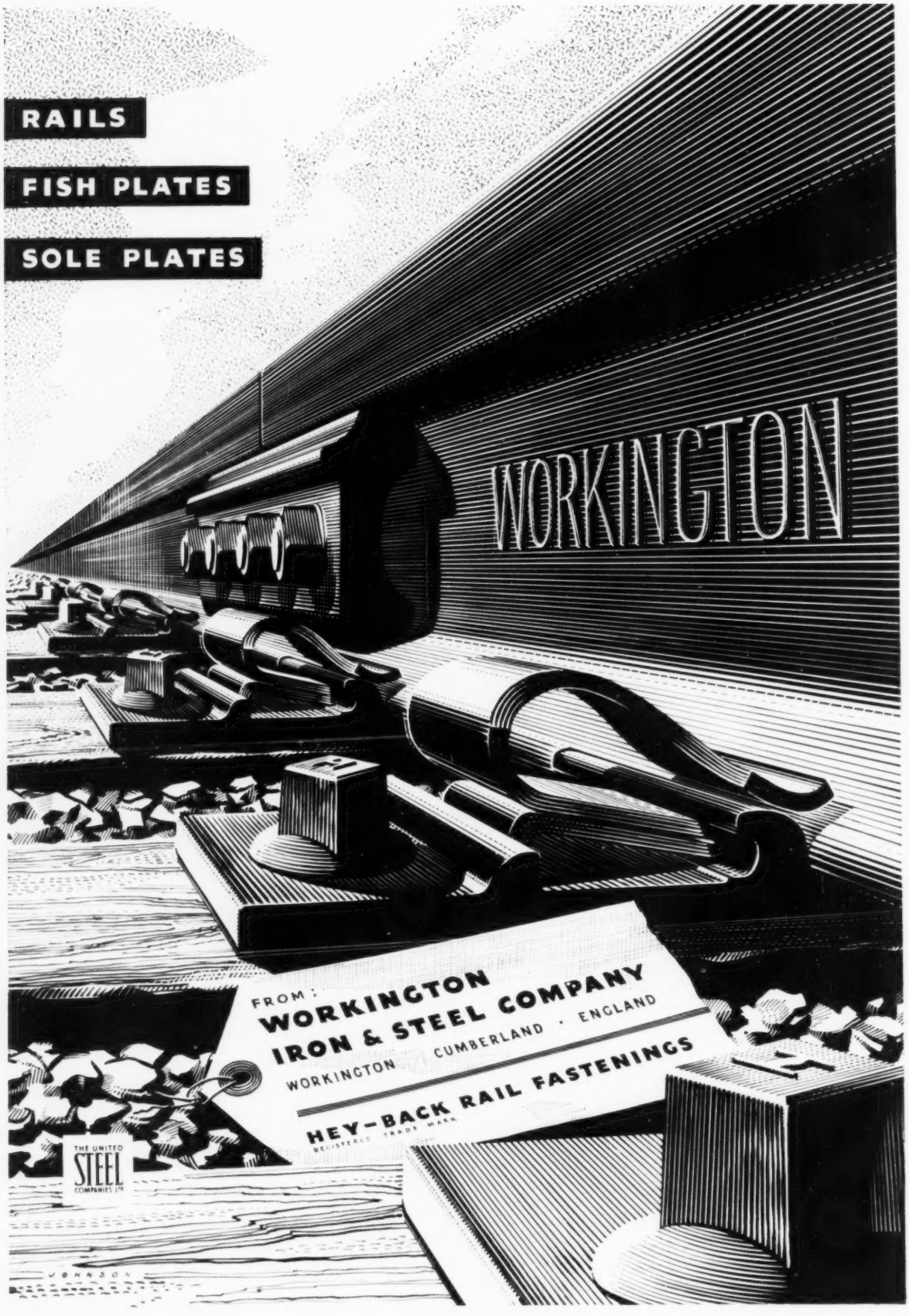
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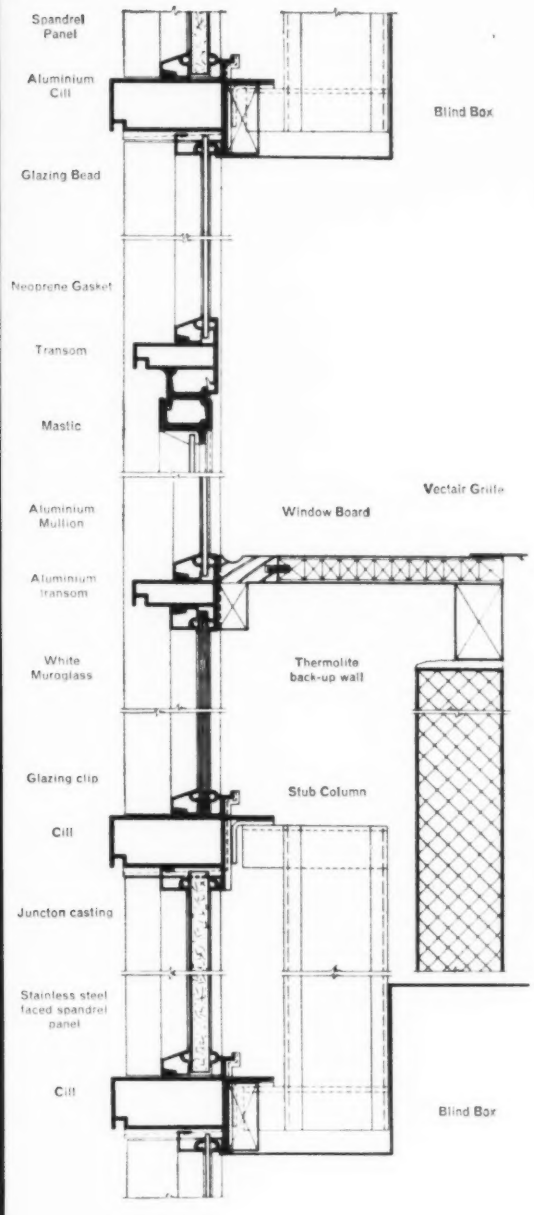
Curtain Walling for Sheffield Laboratories

Architects: A. M. Gear & Associates

These new Sheffield Laboratories for Samuel Fox & Co. Ltd. employ a curtain-wall system of glass and stainless steel, developed by the architects and manufactured and marketed by Crittalls.

Laminated spandrel panels of $\frac{1}{2}$" Asbestolux board are faced with 26 gauge "Silver Fox" stainless steel, polished to a matt finish which keeps down glare and reflectivity. The panels, which are rigidly flat, are manufactured by Flexo Plywood Industries Ltd. The extrusions forming the structural grid are of anodised aluminium, specially treated to resist the heavy industrial atmosphere of a steel works.

The initial cost of using stainless steel is largely offset by remarkably low maintenance. Superficial dirt and dust is removed by wiping with a wash leather when the windows are cleaned. No other maintenance is either desirable or necessary.



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ironmaking
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analysis
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useful books on iron and steel

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practical ironmaking

BY G. D. ELLIOT & J. A. BOND. 280 PAGES. 65 ILLUSTRATIONS

This explanation of basic principles will be of interest not only to students of ironmaking, but to men who make their living in an ironworks. Throughout the book the theory of ironmaking has been presented in a way that can be used to assist day-by-day operations.

PRICE: GT. BRITAIN: £2. U.S.A. AND CANADA: $6 POST FREE

steelmaking for steelmakers

BY A. JACKSON. 276 PAGES. 83 ILLUSTRATIONS

A practical guide, based on nearly 35 years experience of open-hearth steelmaking. It traces developments in refractories, furnace firing, and the control of furnaces by the use of instruments. Particular emphasis is placed on the chemistry of steelmaking reactions. The author urges that oxygen techniques be developed as quickly as possible to enable the open hearth furnace to produce controlled quality steel at production rates competitive with other oxygen processes.

PRICE: GT. BRITAIN: £2. U.S.A. AND CANADA: $6 POST FREE

steelplant refractories

BY DR. J. H. CHESTERS. 728 PAGES. 274 ILLUSTRATIONS

This book provides the manufacturer with a detailed survey of the present refractories position, and gives a firm basis for future development. The text has been completely rewritten, and is supported with numerous additional illustrations and tables. The revised appendices include the new "British Standard Methods of Testing Refractory Materials." The Refractories Journal said of this book "Destined to be, and deserves to be, a best seller."

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OF IRON, STEEL AND FERRO-ALLOYS. 176 PAGES. 8 ILLUSTRATIONS

A section dealing with physico-chemical analysis, together with methods for iron and boron, has been added to this new and enlarged edition. Many of the methods described in previous editions have been revised, and some replaced. These revisions to the late Dr. T. Swinden's original work have been carried out by the Central Research Laboratories of The United Steel Companies.

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foundry sand control

BY DR. W. DAVIES. 216 PAGES. 135 ILLUSTRATIONS

Every foundry sand technologist must look forward to the time when real sand control is exercised to detect fluctuations in sand quality before they are serious enough to cause casting defects. This book presents an effective synthesis of present knowledge and current opinion, directed towards the better *control* of sand properties.

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Obtainable from the Publications Department, The United Steel Companies Limited, P.O. Box 64, The Mount, Broomhill, Sheffield, 10

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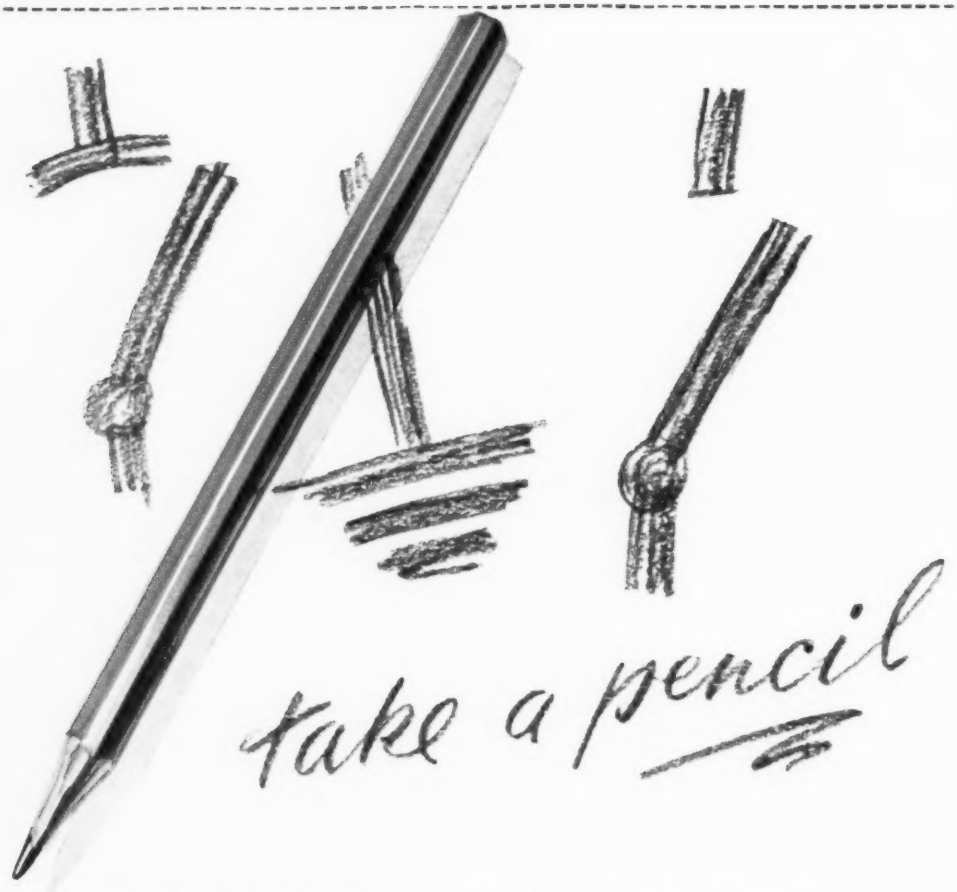

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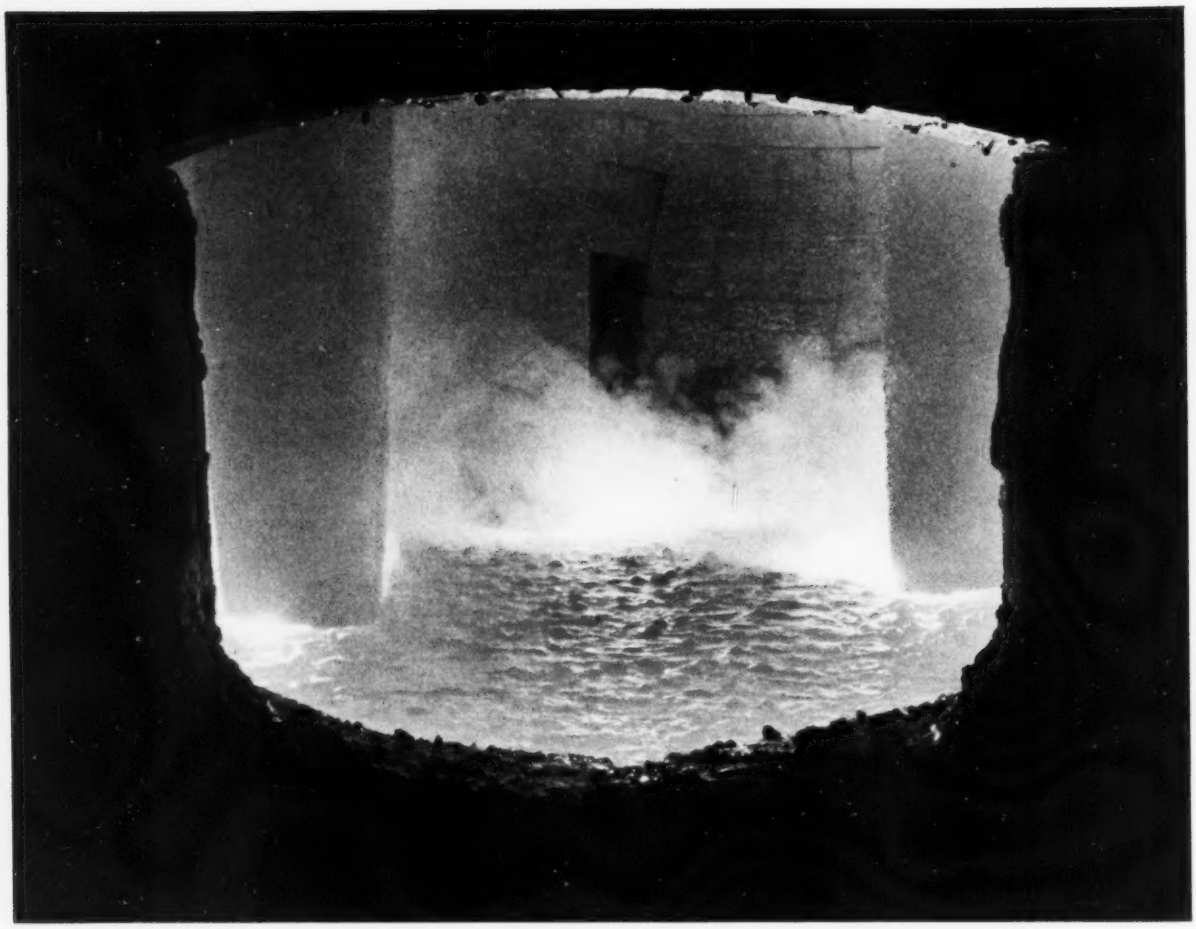

By courtesy of Thomas Firth & John Brown Limited

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Truly through its electrodes an arc furnace draws its breath of electric power. On the high quality and dependability of these lungs rest so much the burden of ensuring the smooth efficiency and economy of the arc furnace as a steel-melting unit. The excellent properties of 'Acheson' graphite electrodes are a sure guarantee of first-rate performance

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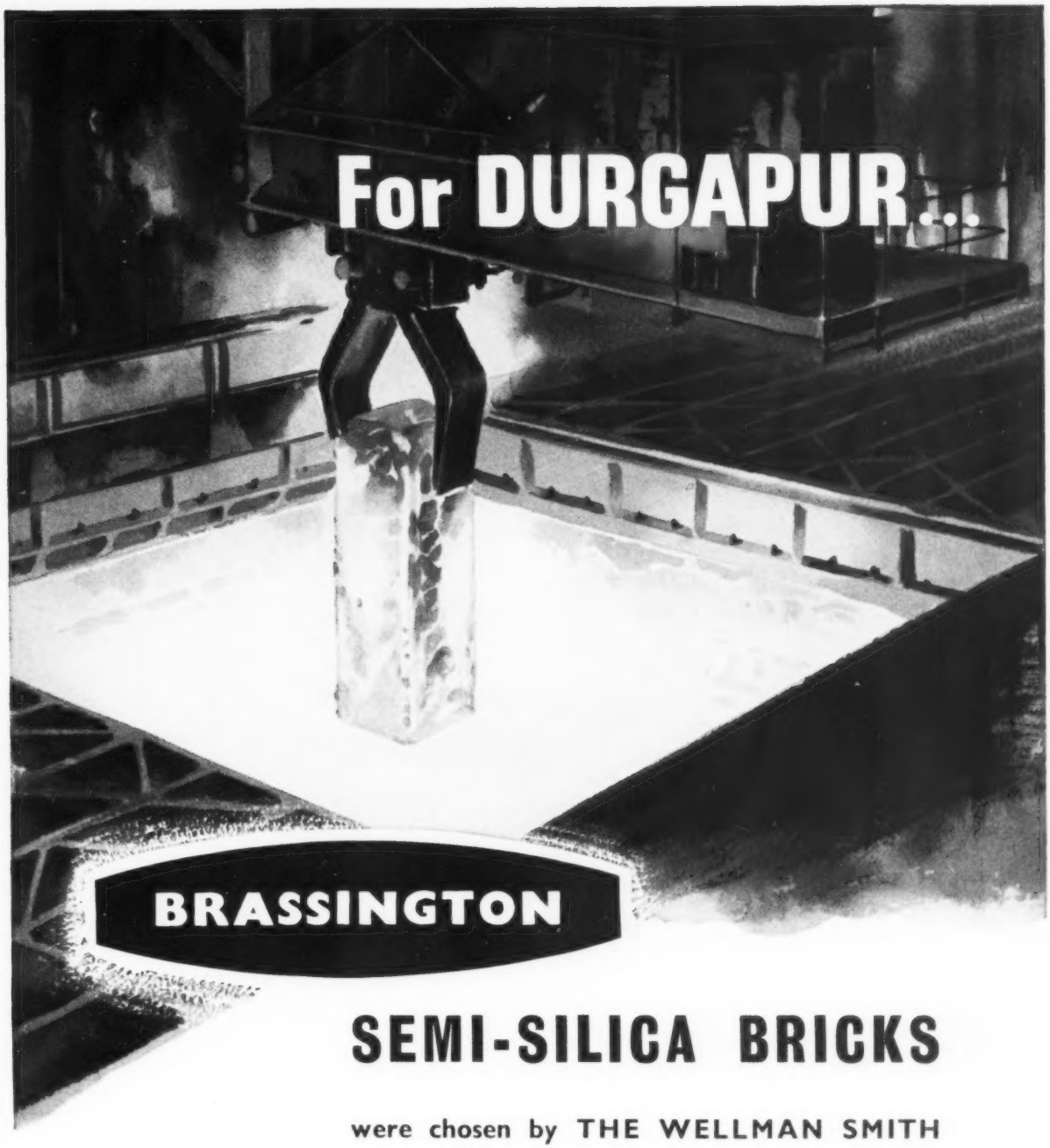

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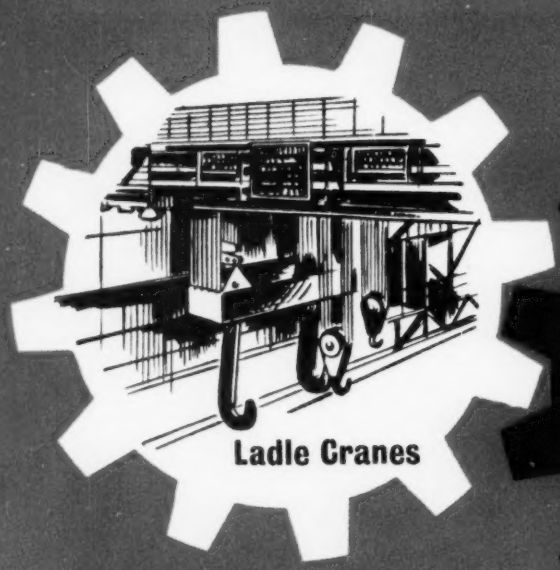
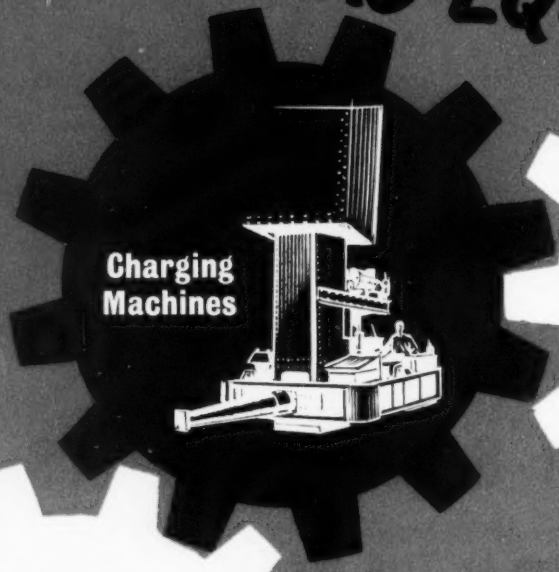


Ladle Cranes

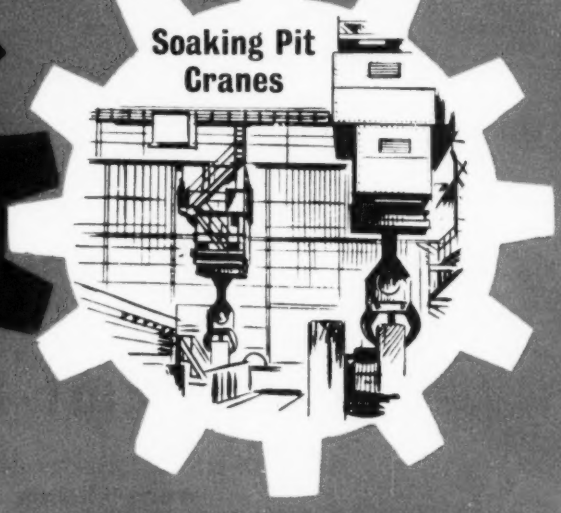
Stripping Cranes

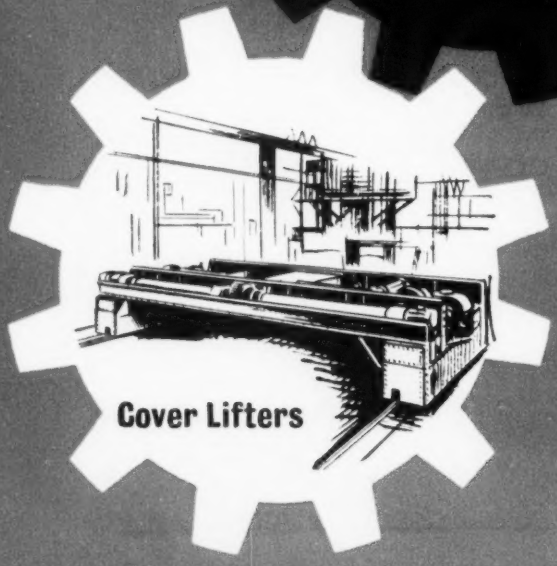
STEELWORKS EQUIPMENT



Charging Machines

Soaking Pit Cranes





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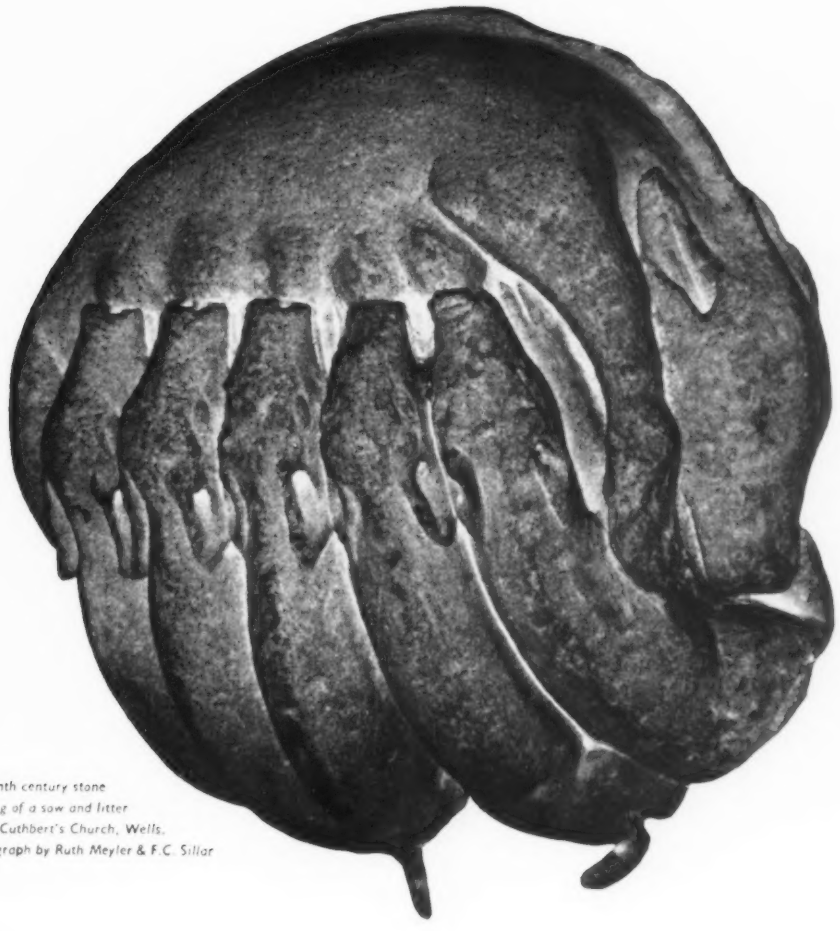


Fifteenth century stone carving of a sow and litter in St. Cuthbert's Church, Wells. Photograph by Ruth Meyler & F.C. Sillar

50 MILLION PIGS GO TO MARKET!

In the early days of the industrial revolution manufacturers frequently looked for familiar and easily recognisable descriptions of their products. To the countryman transplanted into industrial surroundings nothing was more familiar than a pig; a fact which is emphasised by carvings in scores of old churches depicting pigs suckling their litter, rooting for acorns and playing the bagpipes. (Apparently this last pastime was forsworn by pigs many years ago because of unpleasant associations between bagpipes and pigs bladders.) Consequently, when iron from Blast Furnaces was directed into long troughs and from there into short and narrow troughs placed at right angles, a resemblance to sows suckling their appendaged litter led to the description of 'pig iron'.

This series of advertisements illustrates some of the 'ecclesiatical' pigs and emphasises the 50,000,000 'special' pigs which Warner and Company have supplied to Iron Foundries producing High Duty Castings.

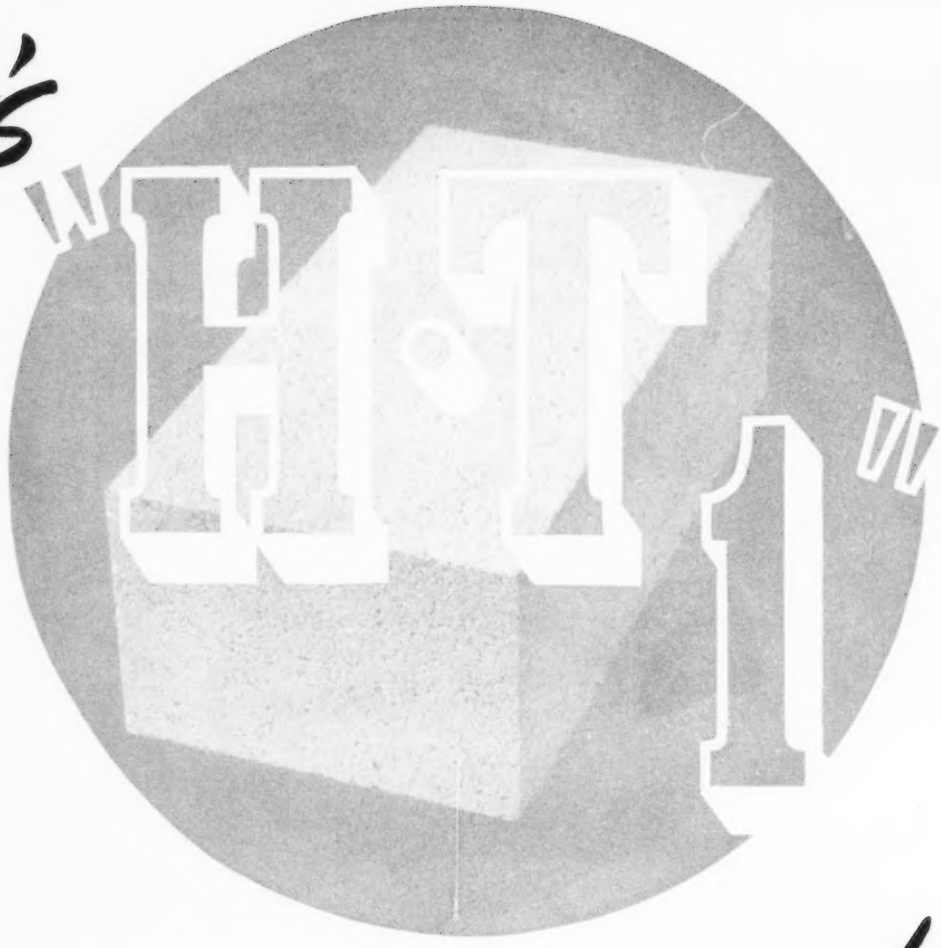
WARNER WARNER WARNER

"Pioneers of Refined Pig Iron"

KA

WARNER & CO. LTD., MIDDLESBROUGH

It's "H.T 1"



from experience!

From experience Gibbons "H.T 1" insulating refractory is the automatic choice of leading furnace manufacturers and users — its combination of low thermal conductivity with resistance to high temperatures has proved remarkably effective in minimising heat losses and raising furnace outputs. The Gibbons "H.T 1" is developed from more than 20 years' experience in the manufacture of insulating refractories and today an entirely new and original manufacturing technique enables us to offer material having unique physical properties at a price you can afford to pay.

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Gibbons (Dudley) Ltd., Dibdale Works, Dudley, Worcs. Telephone: 55141

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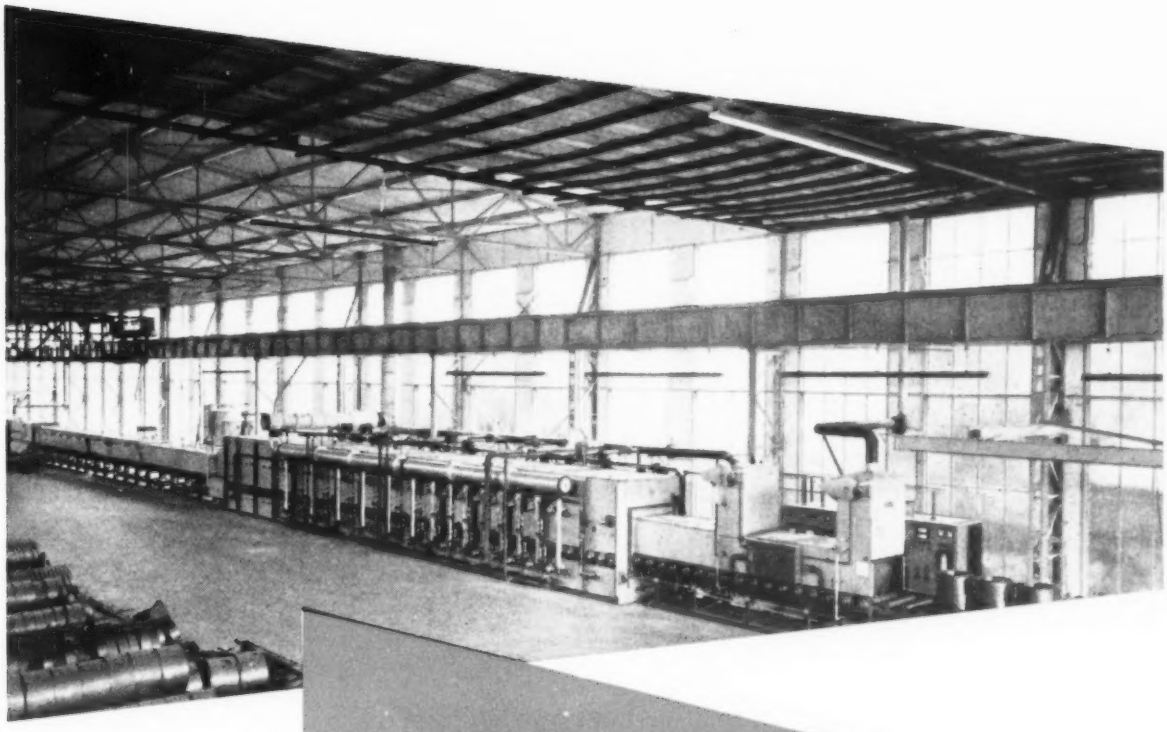

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INCREASE PRODUCTION AND QUALITY LOWER MAINTENANCE AND OPERATING COSTS, OUTPUT UP TO 5 TONS PER HOUR, GAS OR ELECTRICALLY HEATED

Suitable for :—

Strip in Coils
Wire Coils
Bar Materials
Sheets in batches or singly
Tubes
Ferrous or Non-Ferrous material

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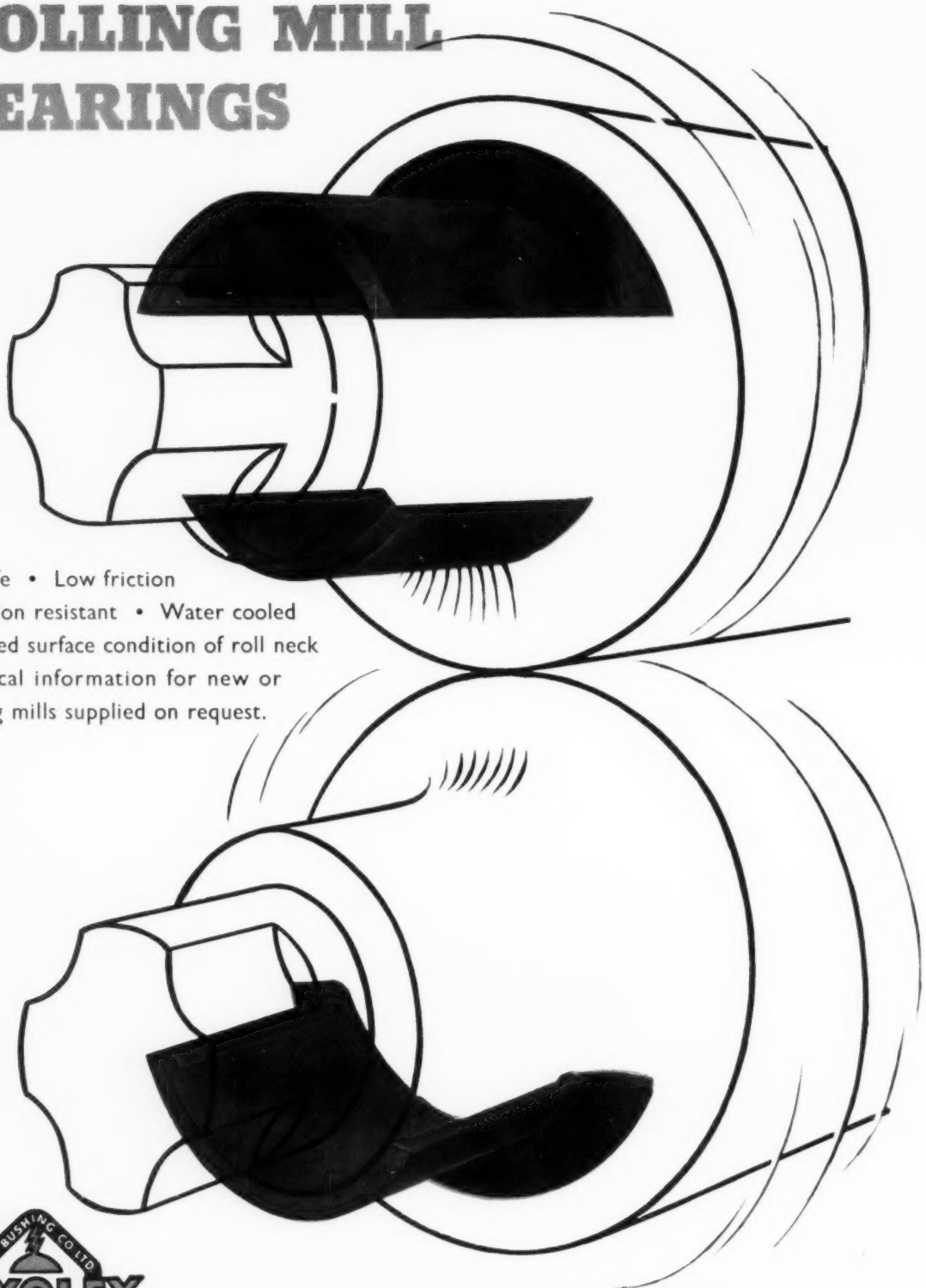

Long life • Low friction
Corrosion resistant • Water cooled
Improved surface condition of roll neck
Technical information for new or existing mills supplied on request.

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THE BUSHING COMPANY LTD. HEBBURN ON TYNE

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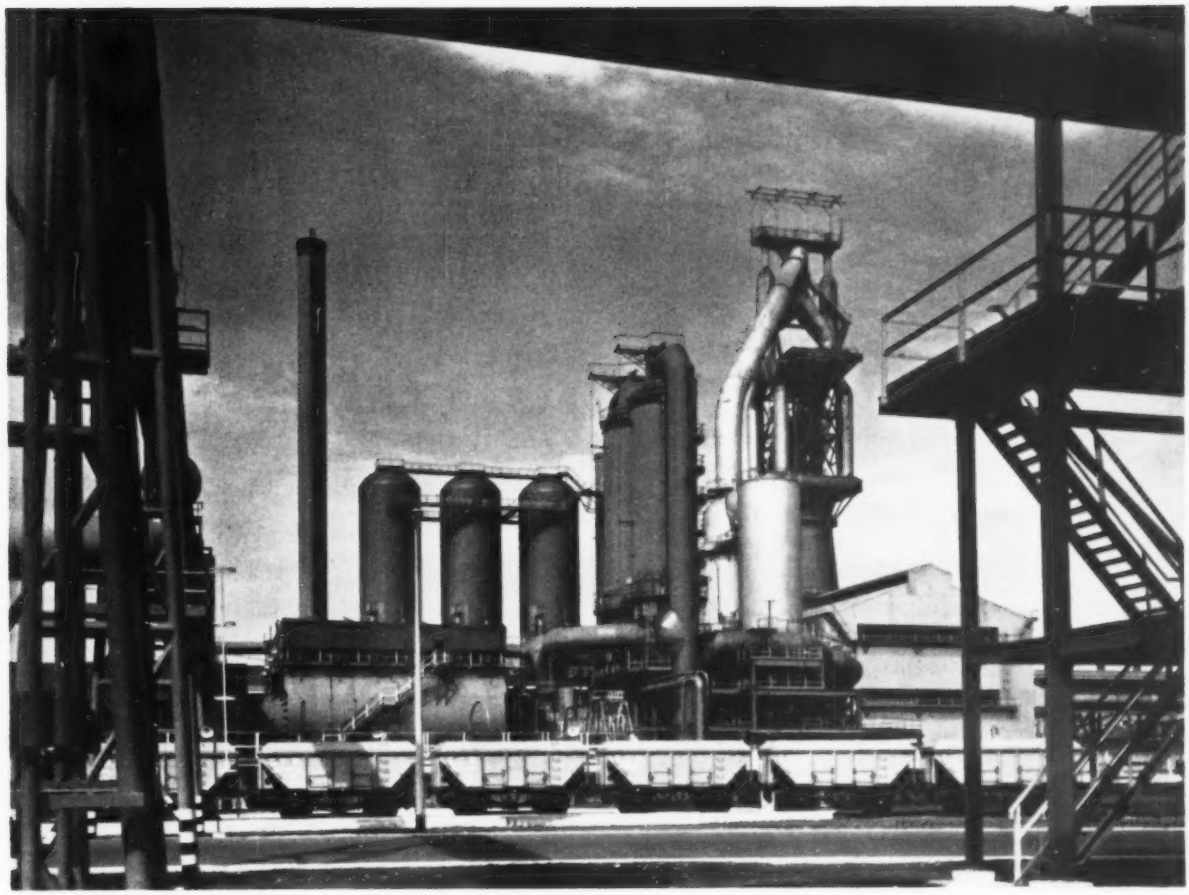

Photo. courtesy Steel Co. of Wales

No. 5 BLAST FURNACE AND GAS CLEANING PLANT

AT THE STEEL COMPANY OF WALES LTD.

INSTRUMENTS AND CONTROLS

SUPPLIED AND INSTALLED BY

REAVELL & CO. LTD.

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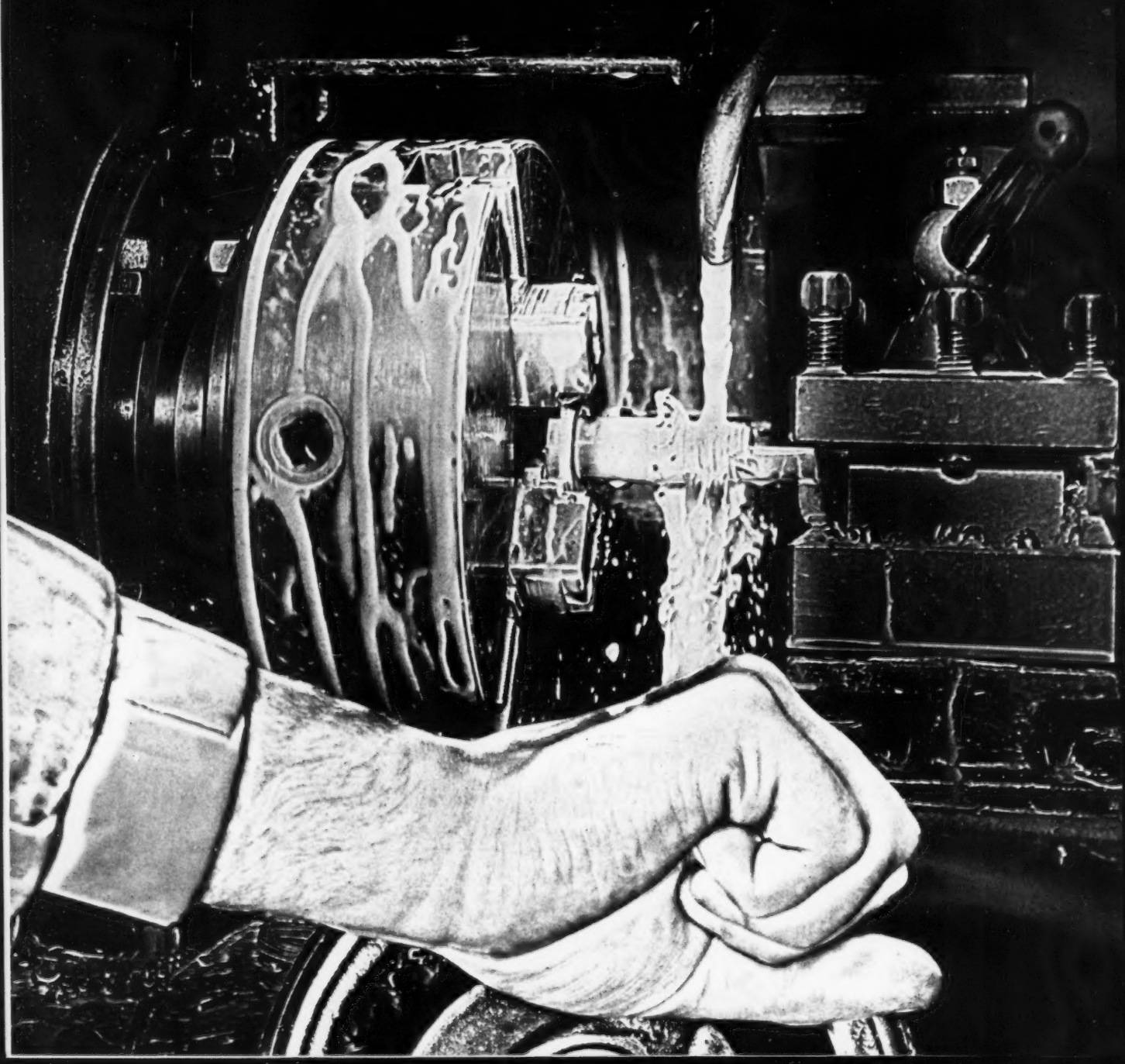
Greater safety for hands



With new Shell Dromus Oils

Most modern soluble cutting oils contain phenolic compounds used as coupling agents between the oil and the emulsifier, for better blending and easier mixing. These phenolic compounds can cause skin irritation, especially where modern high-speed machines are used and the emulsion can concentrate, through the evaporation of water, above the safety level.

Shell research chemists have been working on this problem, which has been causing some concern to Management. After considerable research, Shell Dromus Oils have been reformulated and these new cutting oils now produce bland emulsions, which considerably reduce the risk of skin trouble to operators.

The real difficulty was to find a new coupling agent to replace the phenolic compounds, and Shell finally used what their chemists know as a higher fatty alcohol complex. This solved one problem, but presented another. The new coupling agent was volatile at the high temperatures normally used in blending processes. Further research found a solution to this problem by designing and installing new plant.

The new Dromus Oils are every bit as efficient as before and cost no more. They put Management in the welcome position of being able to minimise working hazards at no extra cost. And machine men need no longer be so worried about skin troubles.

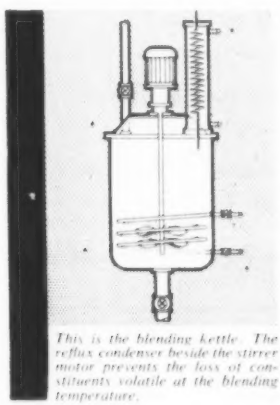
The moral of the story is that Shell research is supremely applicational. The centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organisation have any major lubricating problems, it pays to get in touch with your local supplier of Shell Industrial Lubricants.

The Research Story

Shell chemists in the U.K., in Holland and in the U.S.A., prepared and examined hundreds of experimental soluble oils, and established that certain combinations of fatty alcohols could be used in place of phenolic compounds with no loss of efficiency. They set to work to discover the best combination and developed a higher fatty alcohol complex which fitted exactly. Then they realised that to blend this new coupling agent into soluble oils would require special plant and new blending techniques.

Exhaustive testing of blend stability, emulsion stability, anti-corrosion and machining properties led to selection of the most promising blends. A pilot plant was set up to produce batches of these for use in field trials.

This field testing and final development proceeded for two years whilst production plants were erected at points so chosen as to give the most economical and rapid delivery throughout the United Kingdom.

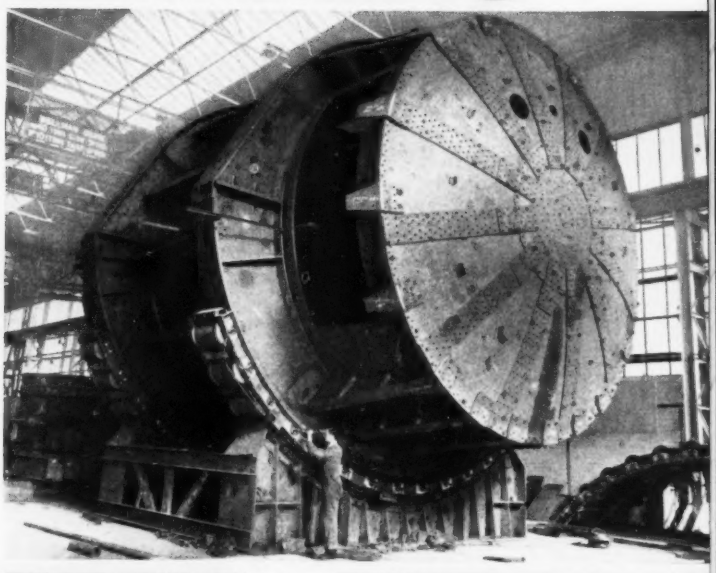


This is the blending kettle. The reflux condenser beside the stirrer motor prevents the loss of constituents volatile at the blending temperature.

NEW SHELL DROMUS SOLUBLE CUTTING OILS

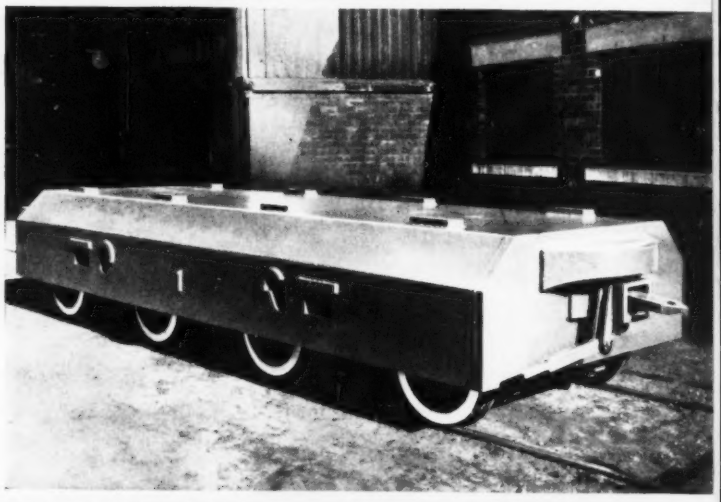
another proof of Shell leadership in lubrication

NEWTON CHAMBERS AND DURGAPUR



SHOP ASSEMBLY OF 800 TON HOT METAL MIXERS

Newton Chambers, under contract to Wellman, Smith Owen Engineering Corporation Limited, have supplied the following equipment for the Indian Iron and Steel Works at Durgapur.



BOGIE TYPE INGOT CASTING CARS WITH ALL WELDED BODY

- ✳ 90 Ingot Casting Cars.
- ✳ 65 Charging Box Bogies.
- ✳ 260 Charging Boxes.
- ✳ 2 x 800 ton capacity Hot Metal Mixers.
- ✳ Structural steel work for 6 x 150 ton Ladle Cranes.

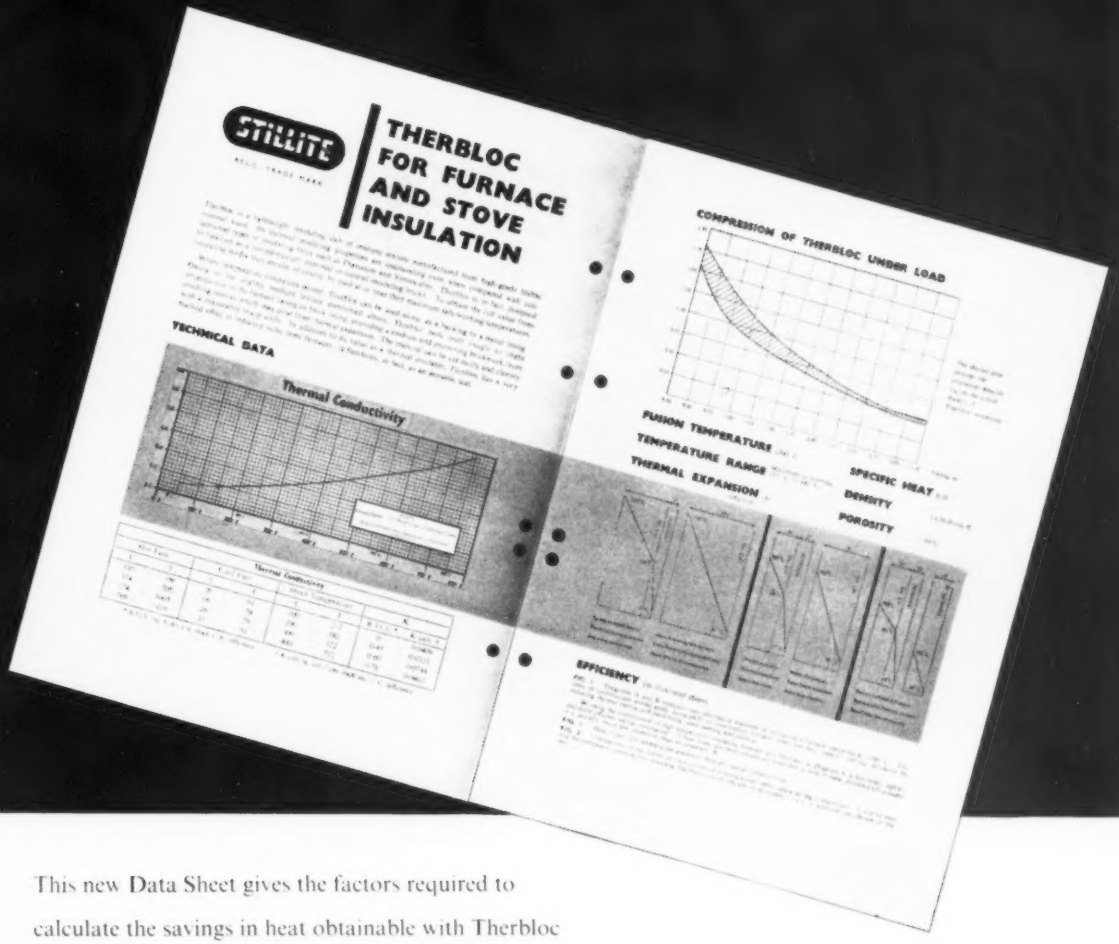
The orders were completed well ahead of schedule.

CHARGING BOX BOGIES COMPLETE WITH CHARGING BOXES

NEWTON CHAMBERS

ENGINEERING DIVISION · THORNCLIFFE · SHEFFIELD

New up-to-date DATA on FURNACE & STOVE INSULATION



This new Data Sheet gives the factors required to calculate the savings in heat obtainable with Therbloc mineral wool insulation used either by itself or as a backing to refractories or insulating brick. Graphs of 'K' values and practical examples are included.

STILLITE

Regd. Trade Mark

STILLITE PRODUCTS LIMITED

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TO STILLITE PRODUCTS LTD., 15 WHITEHALL, LONDON S.W.1

Please send Therbloc Data Leaflet No. 5/60

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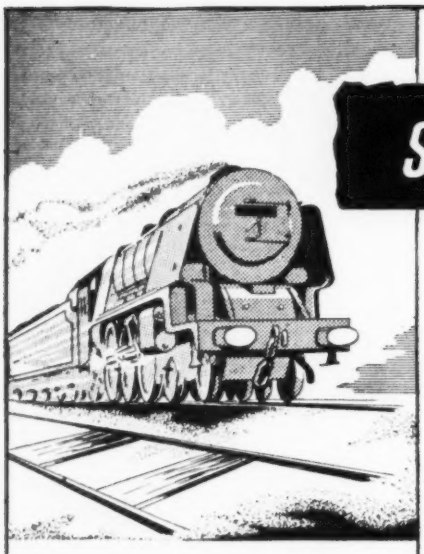
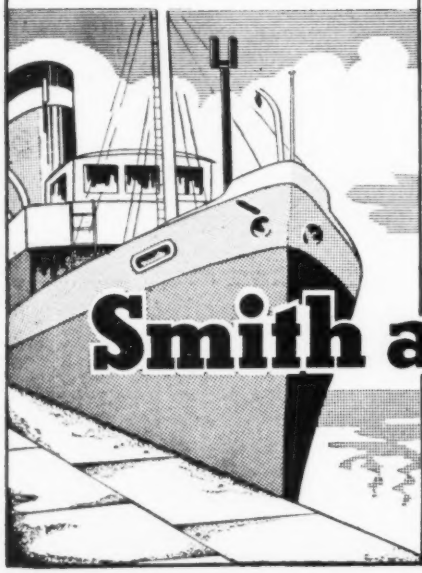
Just attach this coupon to your letterhead

Journal of the Iron and Steel Institute





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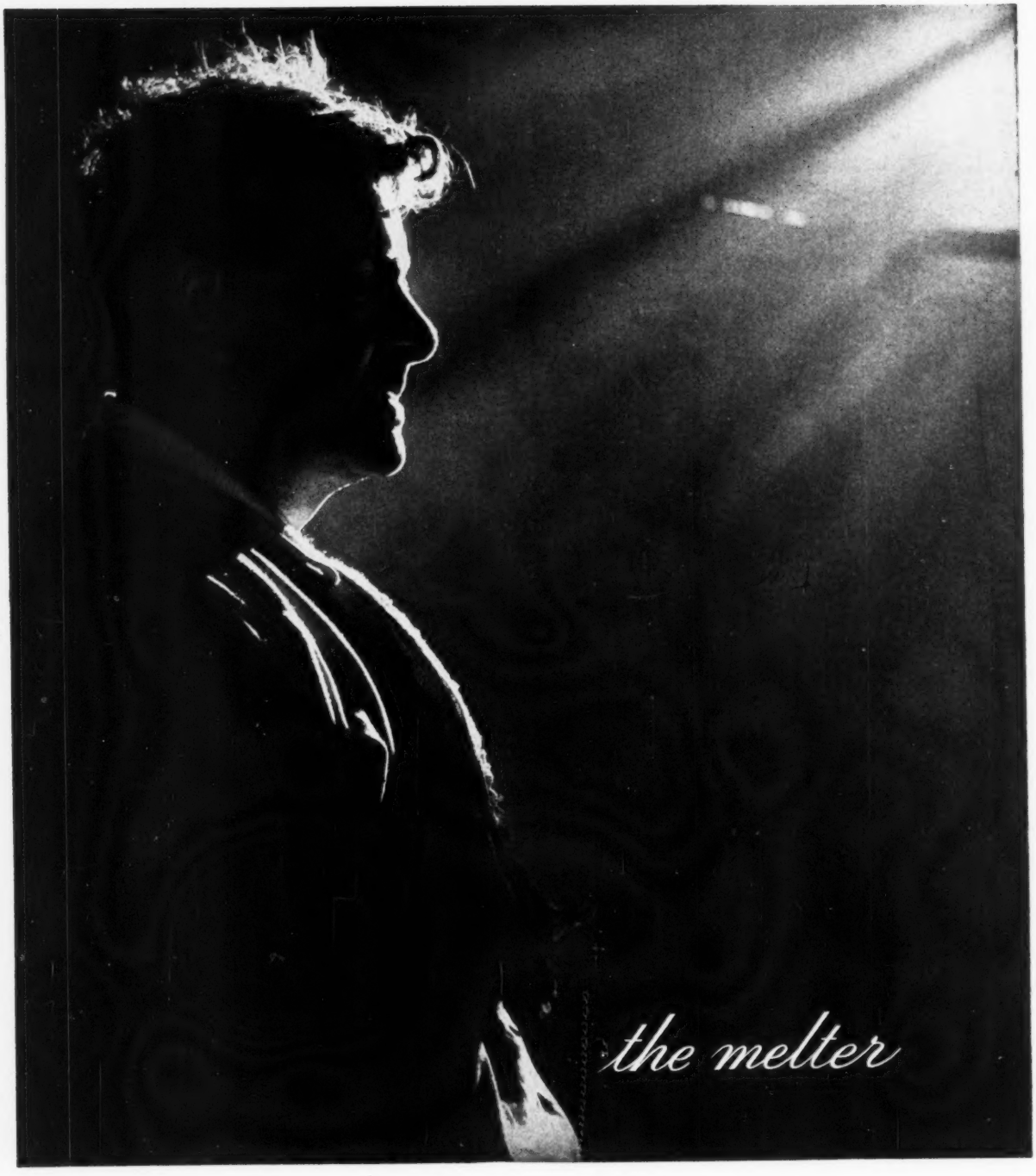

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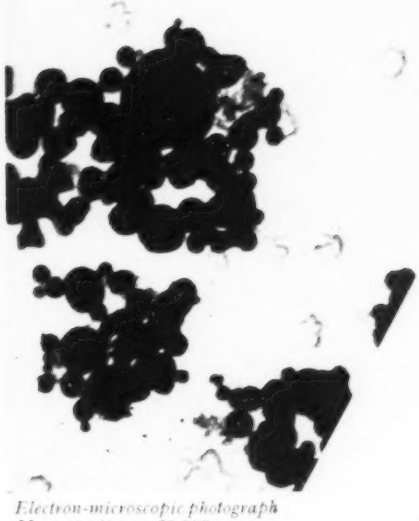

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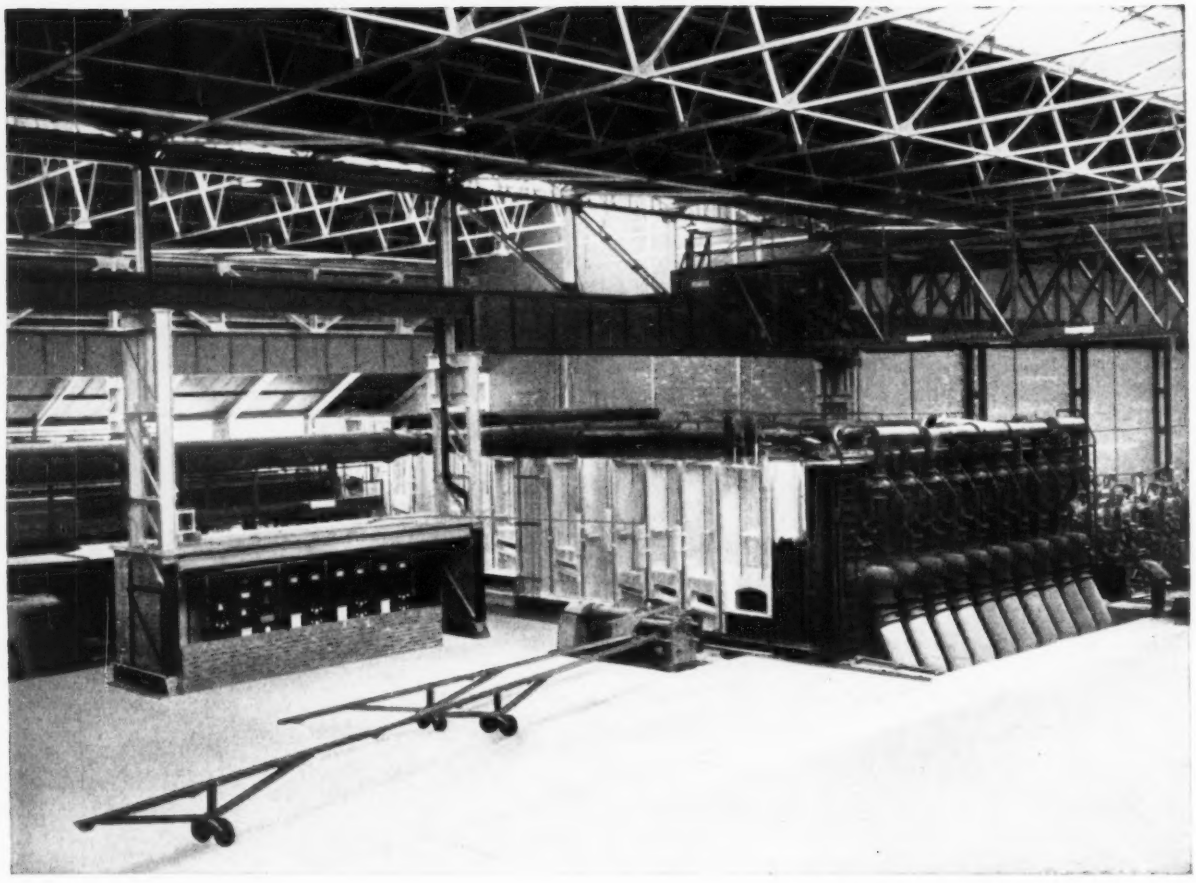

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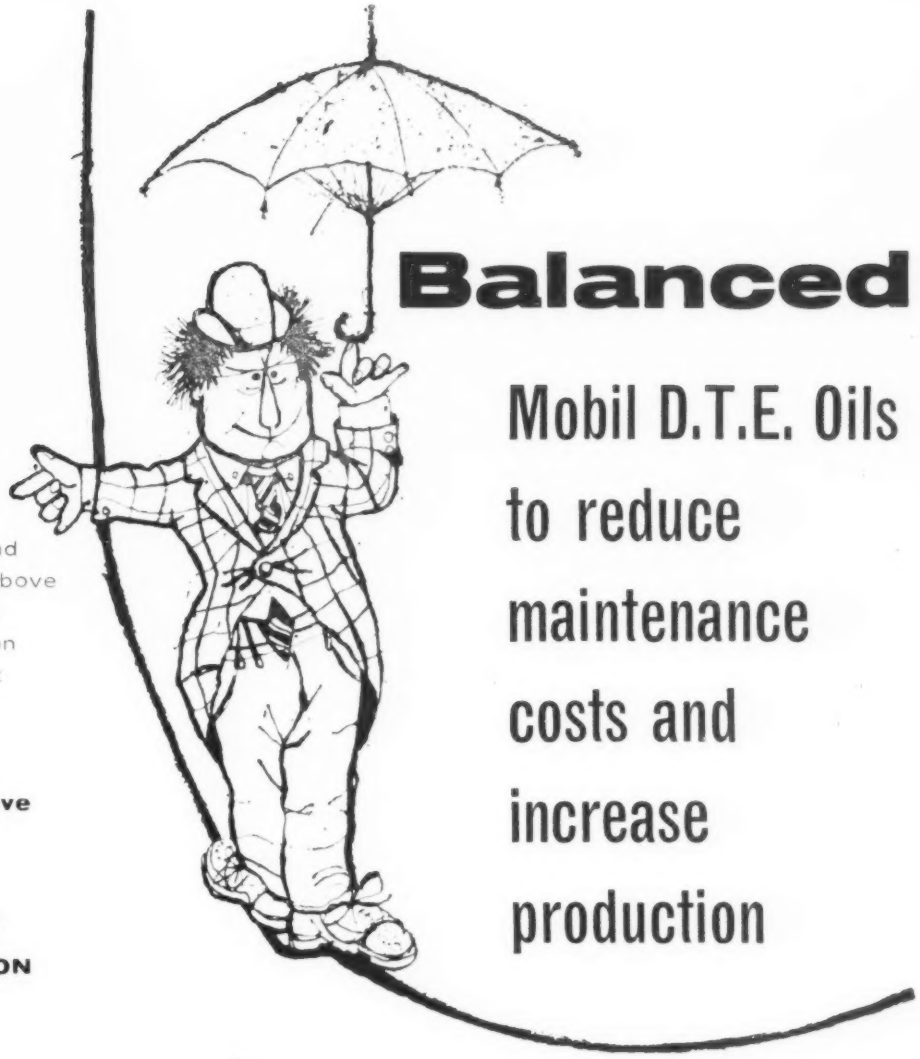

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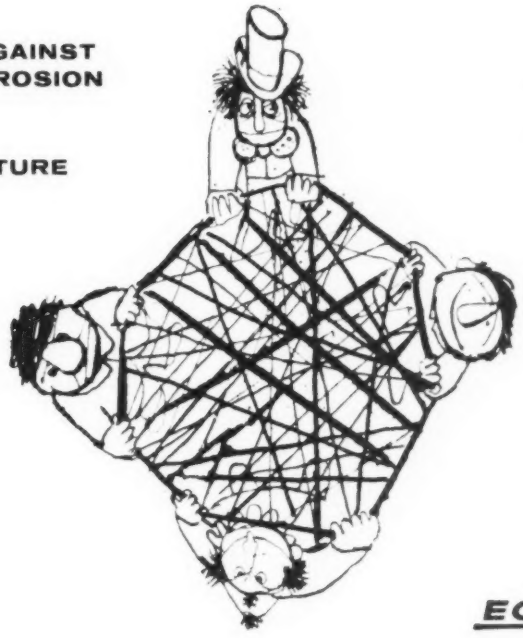

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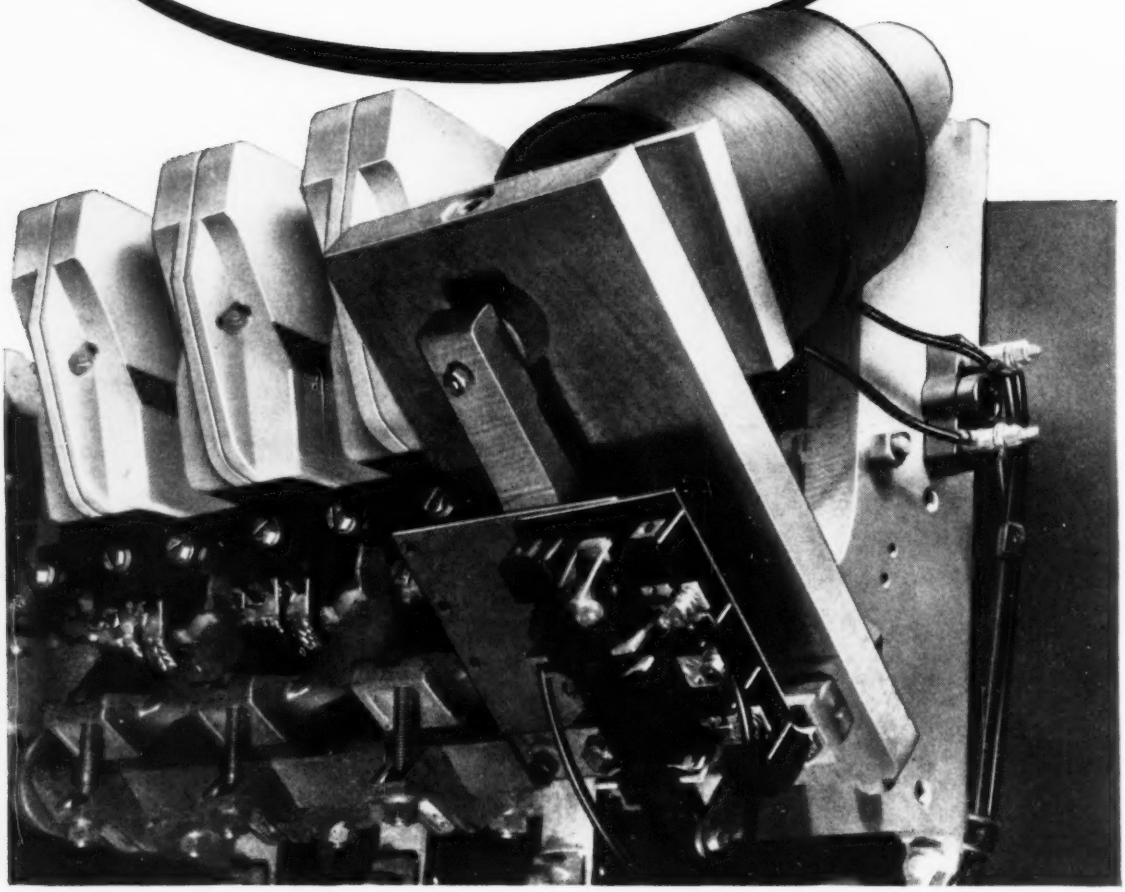

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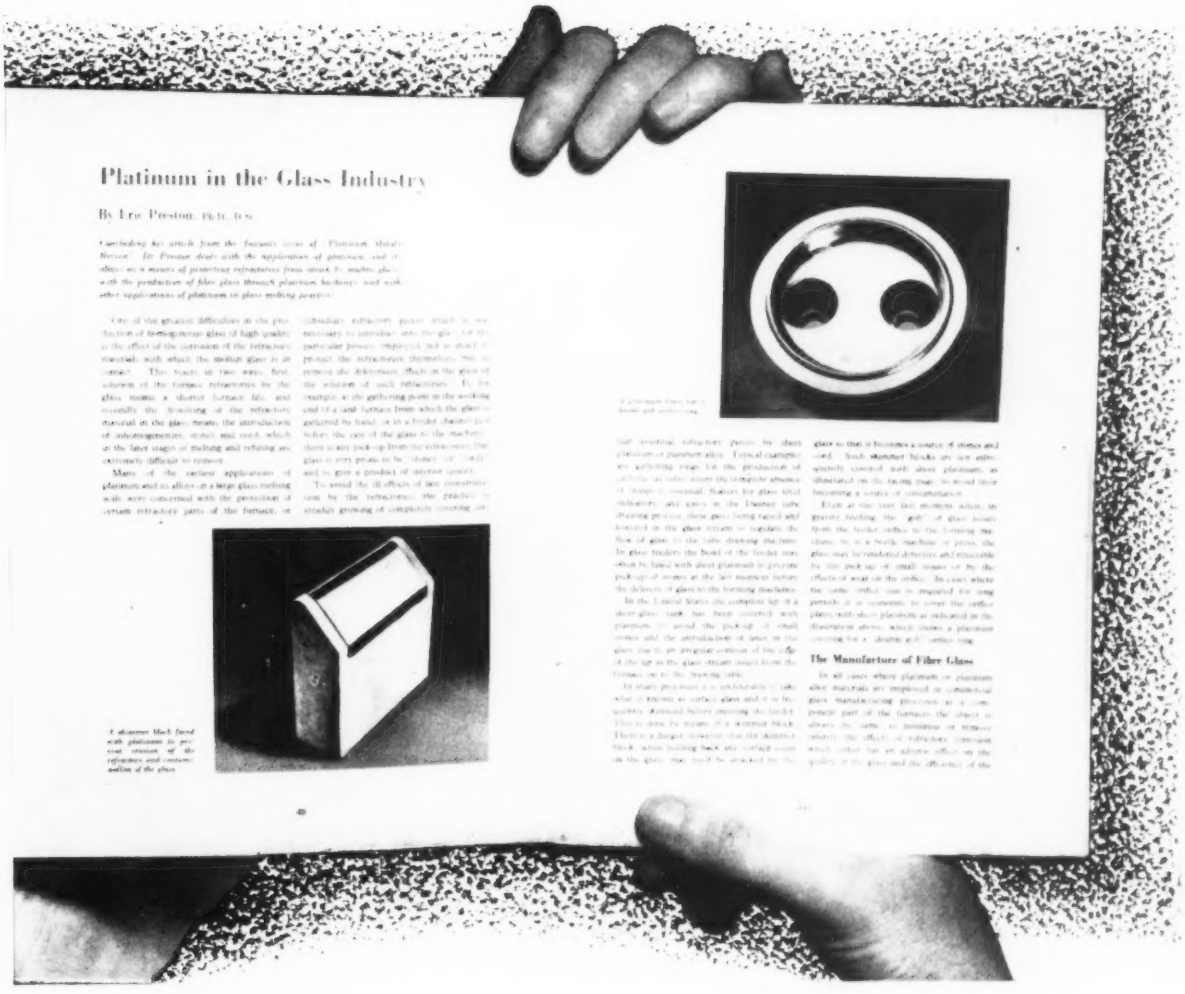

One of the articles to be found in the current issue of Platinum Metals Review – "Platinum in the Glass Industry" – will be of interest not only to those engaged in the glass industry but to anyone wishing to keep abreast of modern production techniques.

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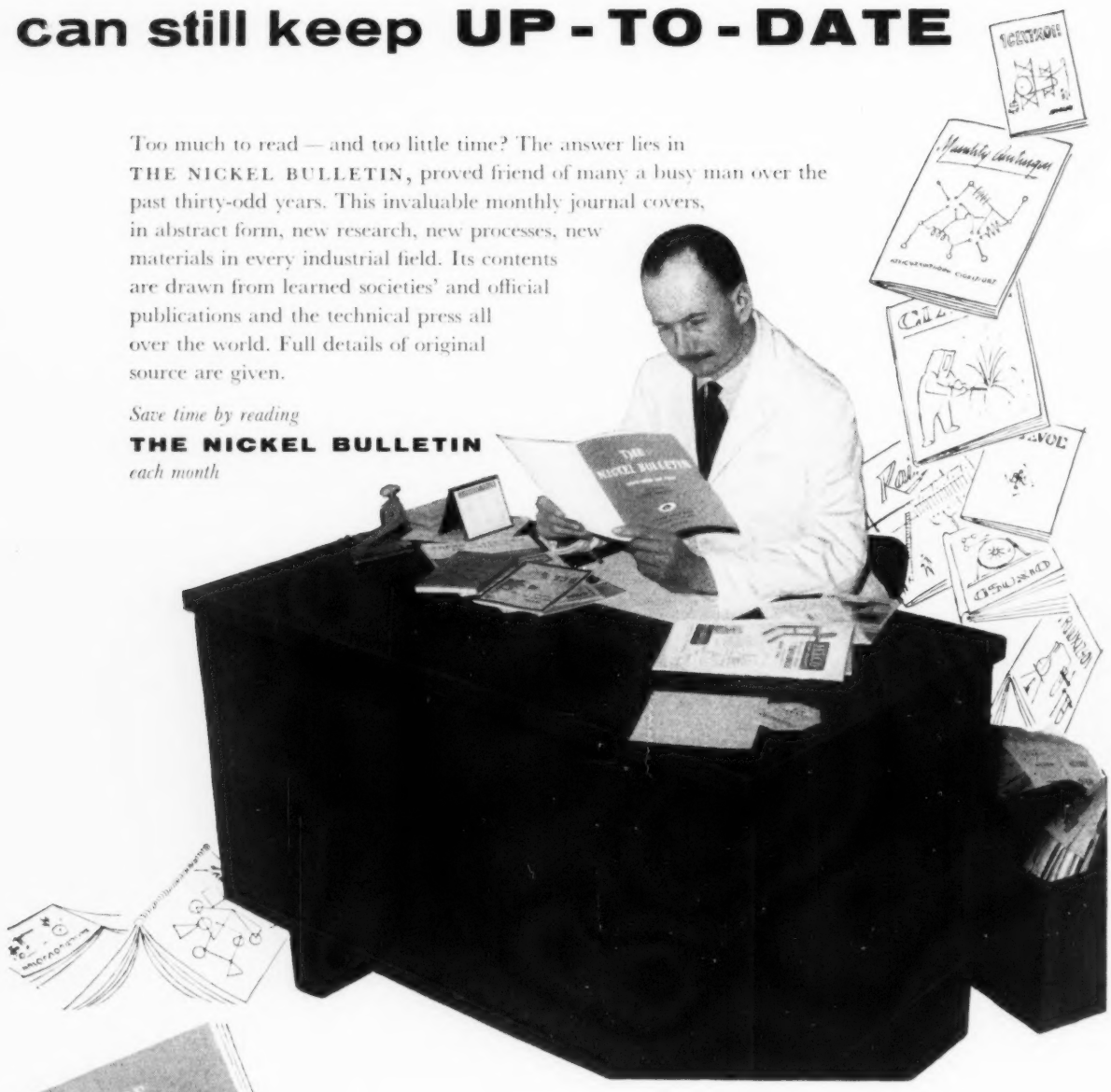

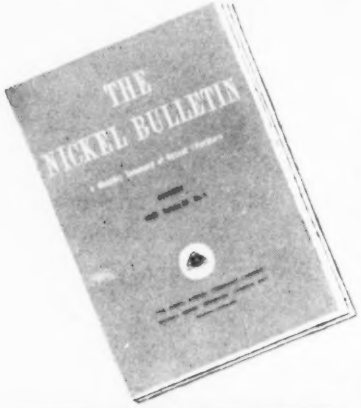

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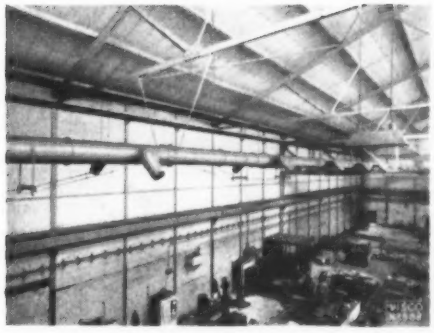
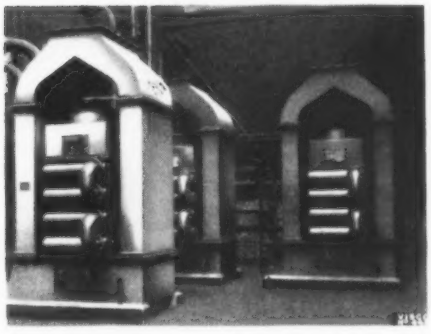
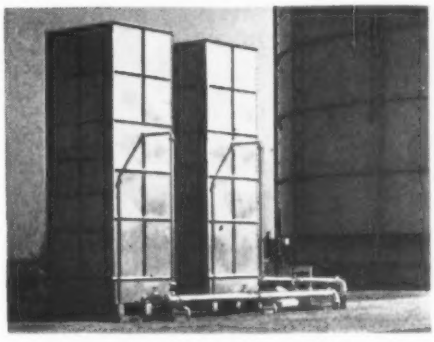


Heating and Ventilating Plant. Firth-Vickers Stainless Steel Ltd.



Visco Spray Blast Oil Coolers. At a large steelworks.



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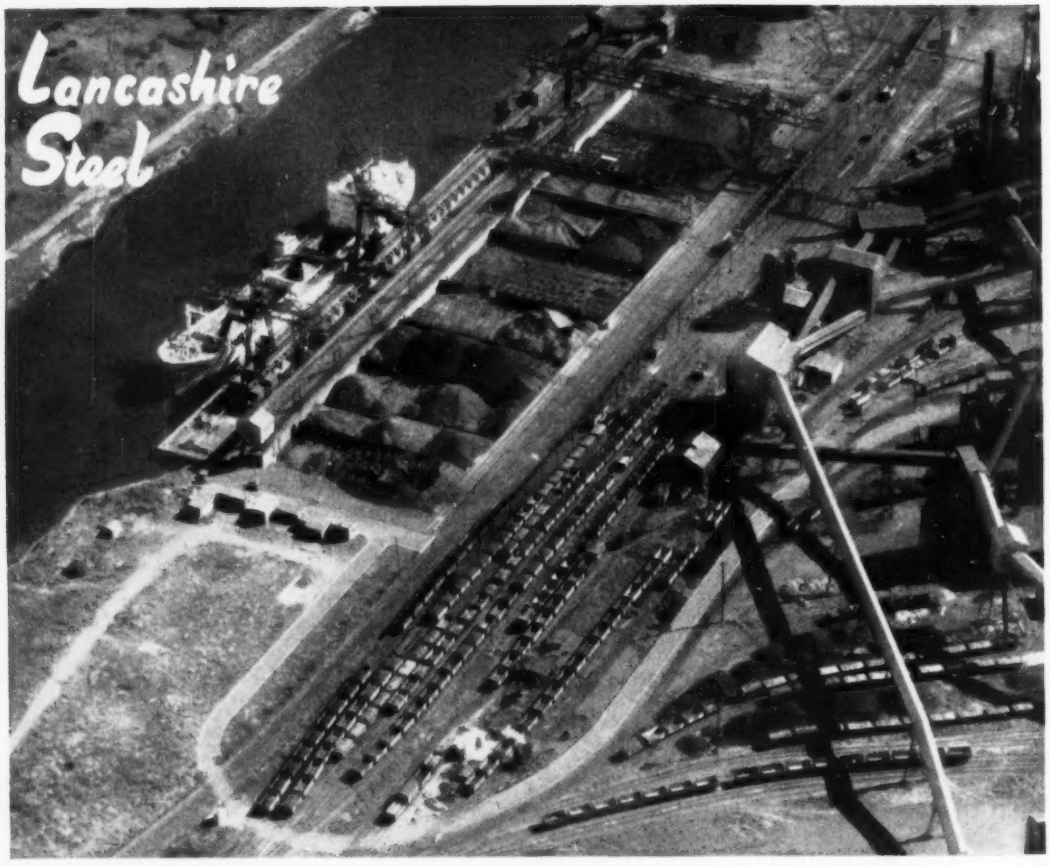

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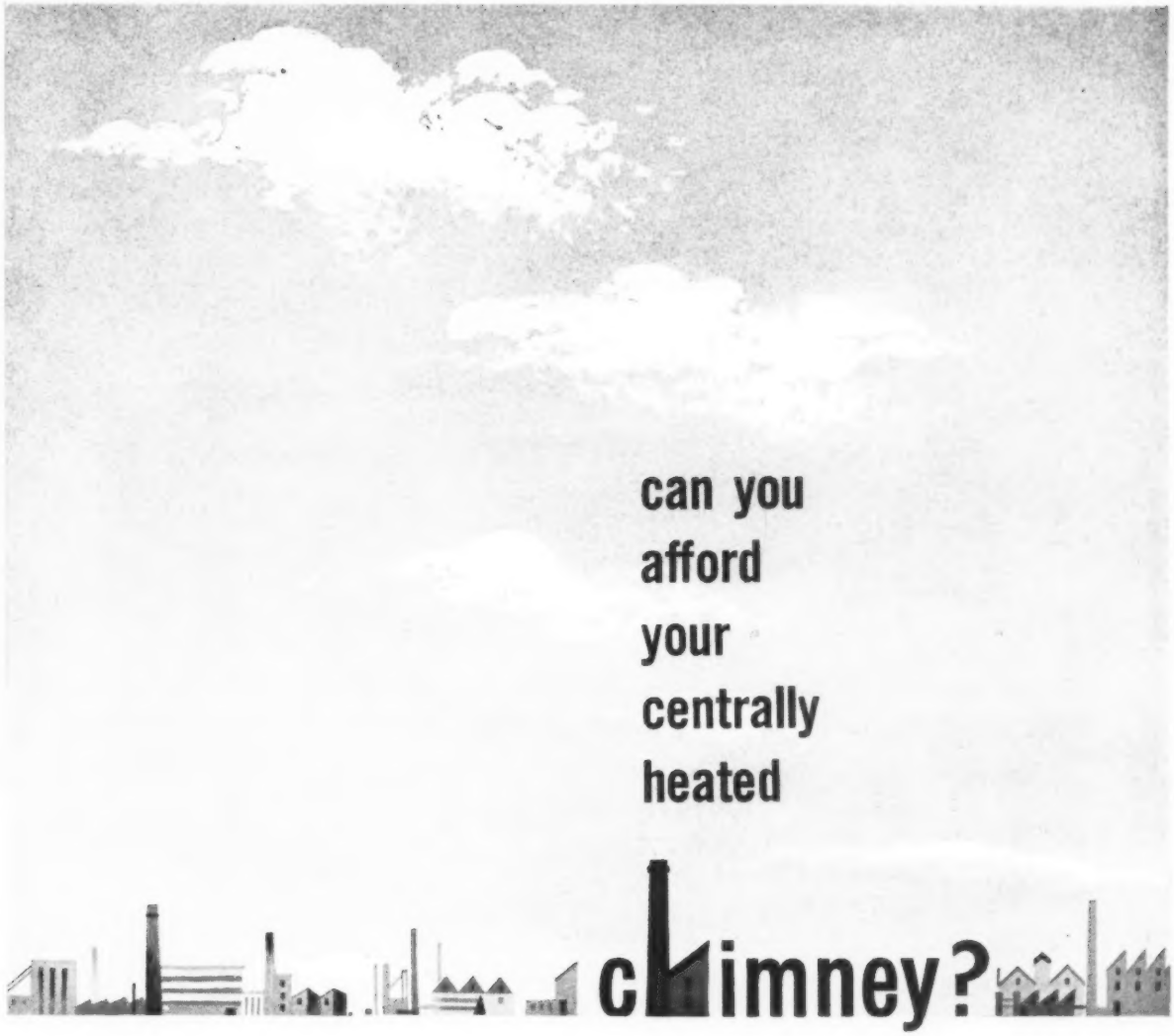

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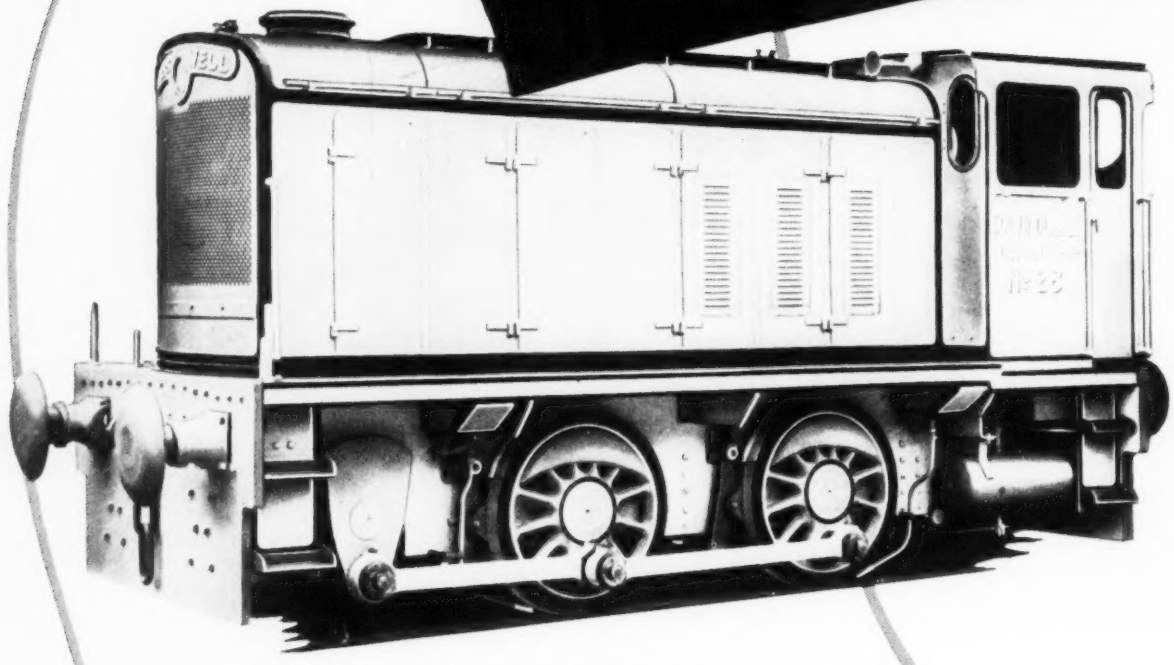

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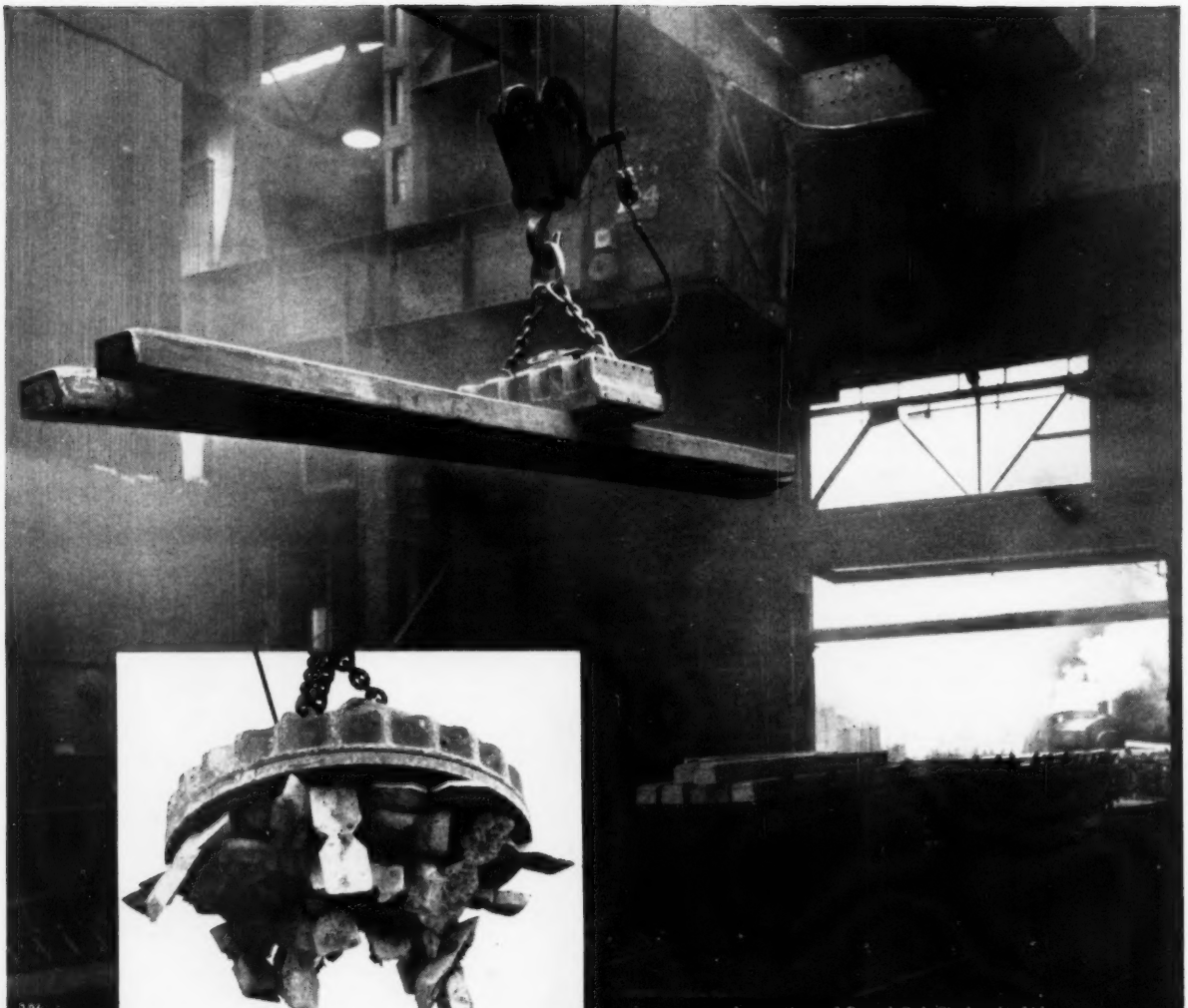

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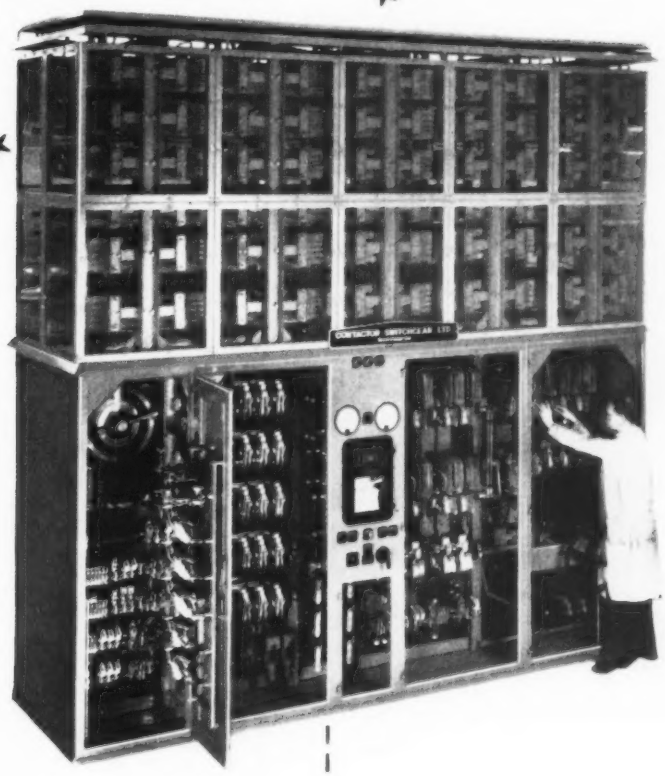

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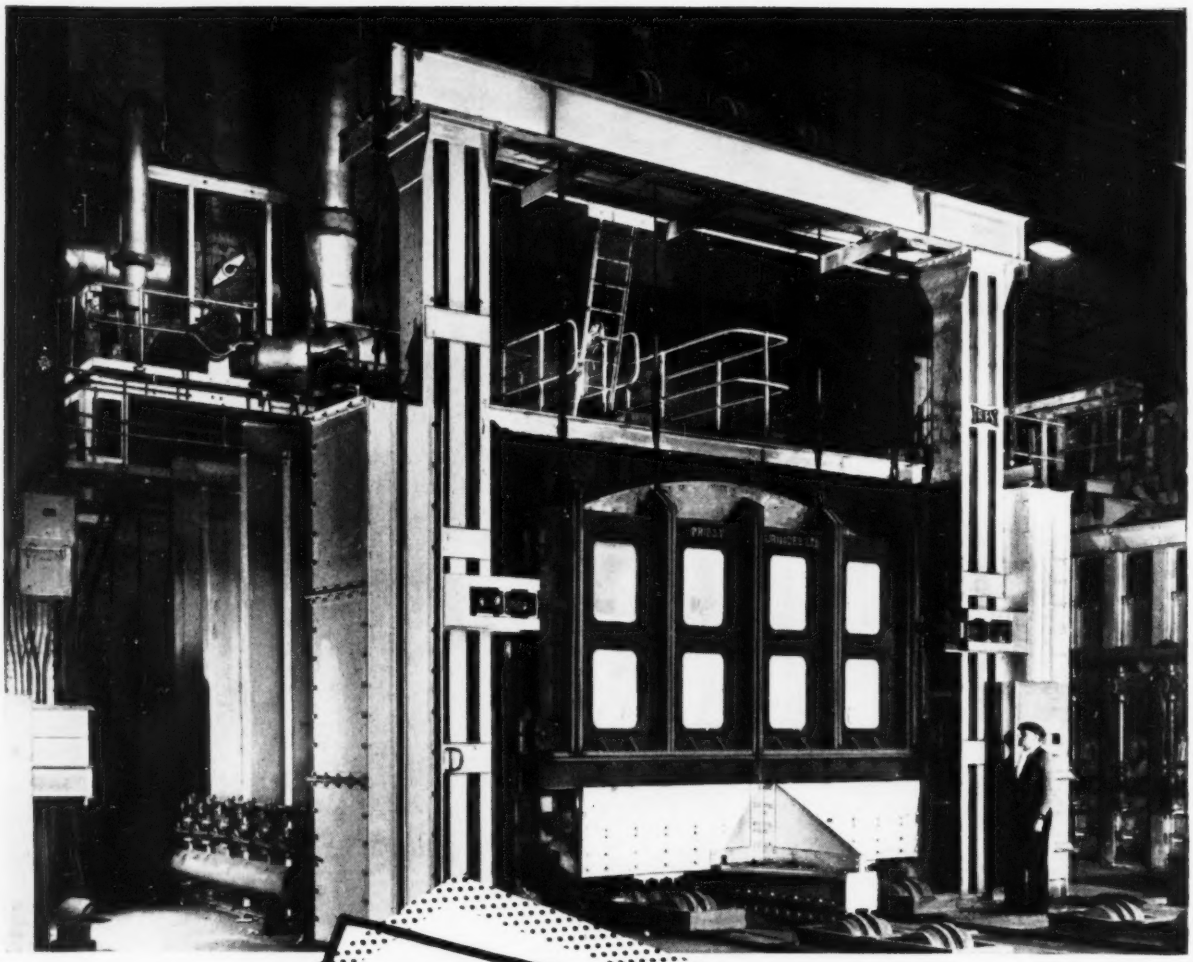

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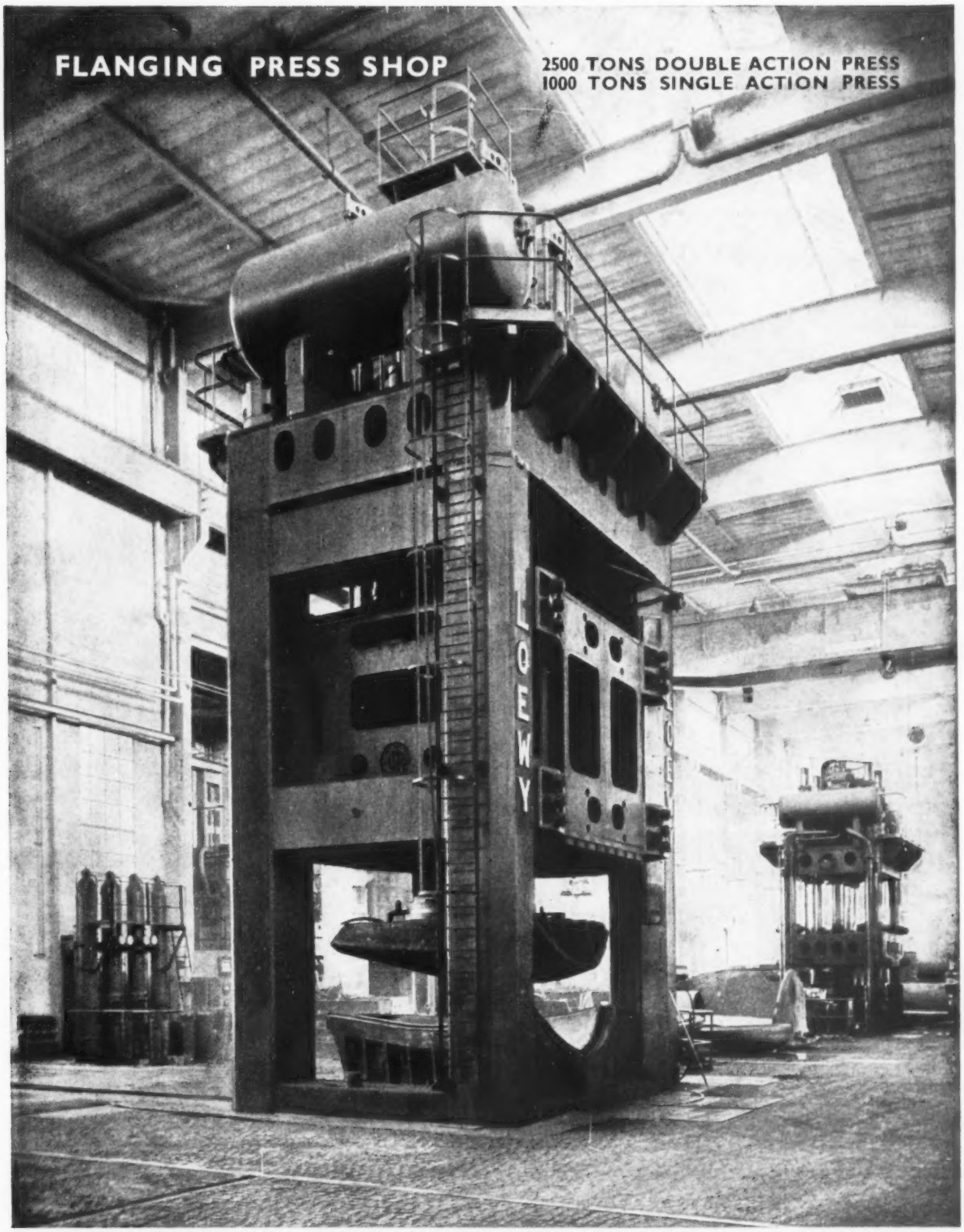

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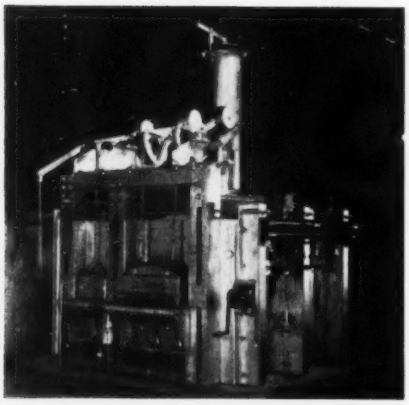

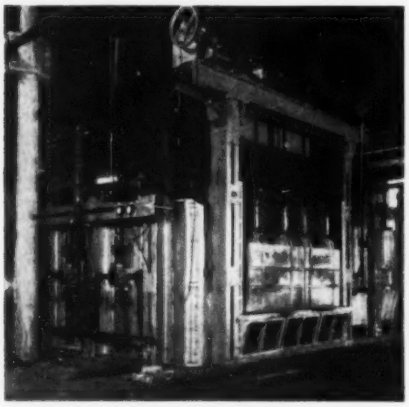

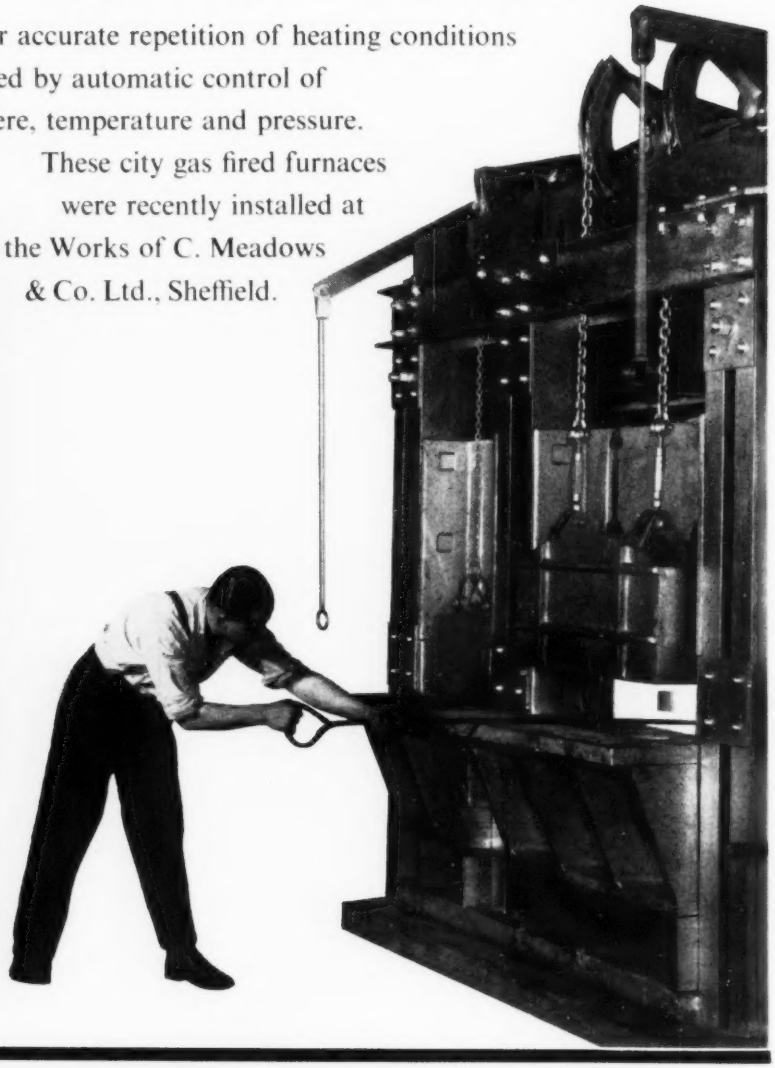

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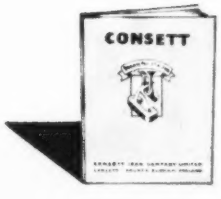

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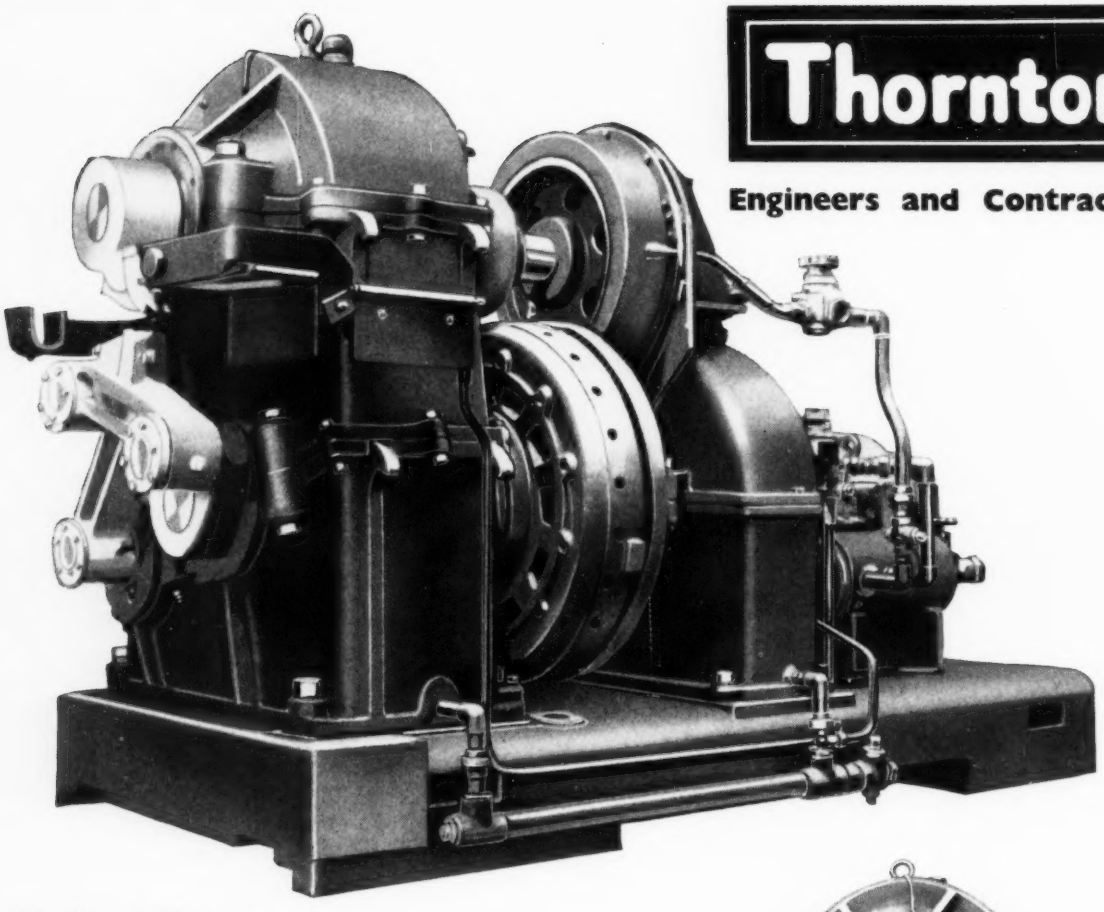

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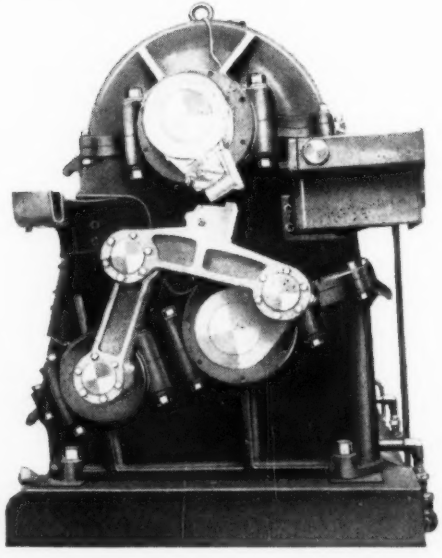

B. THORNTON LIMITED

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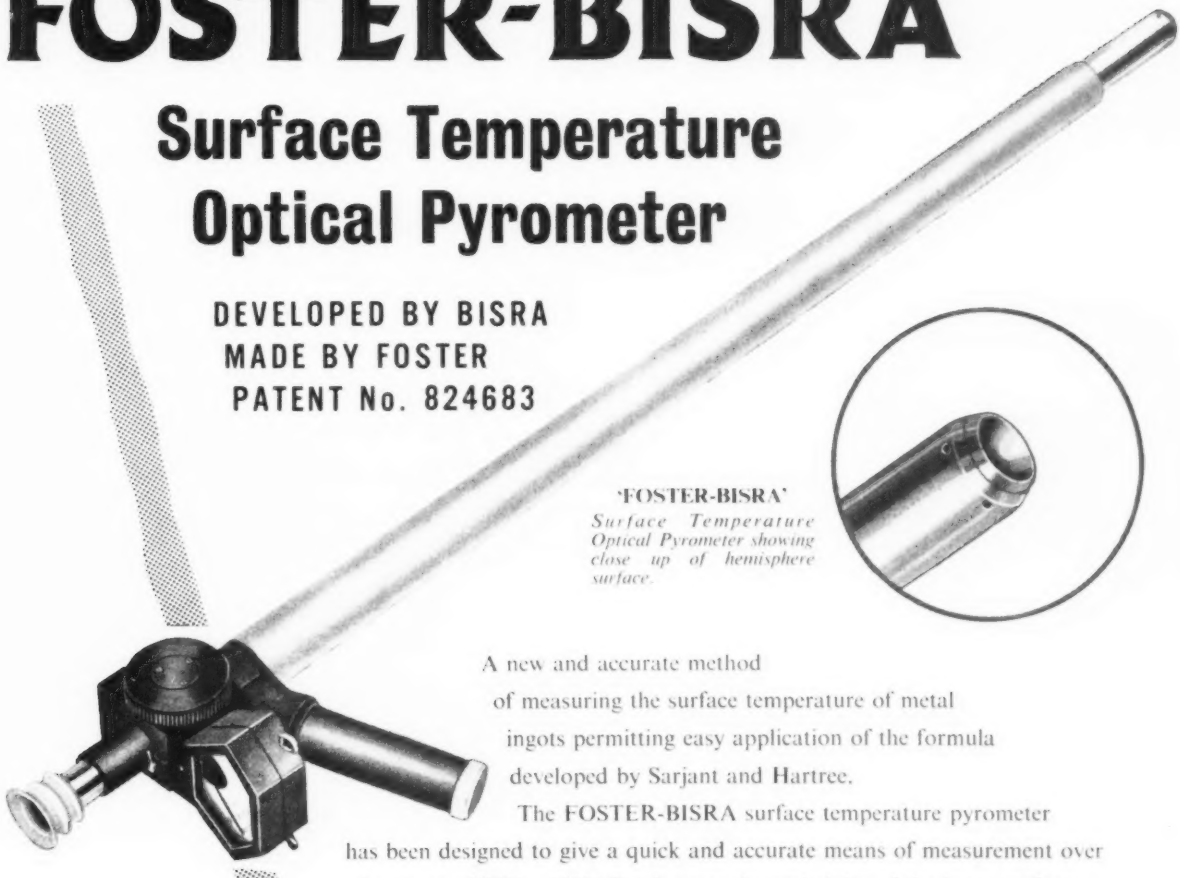
FOSTER-BISRA

Surface Temperature Optical Pyrometer

DEVELOPED BY BISRA
MADE BY FOSTER
PATENT No. 824683



'FOSTER-BISRA'
Surface Temperature Optical Pyrometer showing close up of hemisphere surface.

A new and accurate method of measuring the surface temperature of metal ingots permitting easy application of the formula developed by Sarjant and Hartree.

The FOSTER-BISRA surface temperature pyrometer has been designed to give a quick and accurate means of measurement over the range of 700° —1300° C. whatever the emissivity of the ingot surface. It comprises a reflecting hemisphere and optical system incorporated in an extension tube of a disappearing-filament optical pyrometer focussed on a small aperture in the hemisphere. During measurement, the hemisphere head is inserted in the furnace in contact with the ingot surface. Due to the high reflectivity of the hemisphere's surface, "black body" conditions are simulated on the ingot surface at the point of measurement. The effect of scale on the surface under examination is unimportant and the instrument does not need water cooling or air purging so that direct measurement of the metal surface temperature by a light, portable, quick reading instrument is thus made possible.

For full details contact :

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Members of B.I.M.C.A.M., S.I.M.A. and S.I.R.A. — Telephone : Letchworth 984-5-6 — Telegrams : Resilia, Letchworth

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ONE OF THE WORLD'S LARGEST MANUFACTURERS OF BLAST FURNACE CARBON...

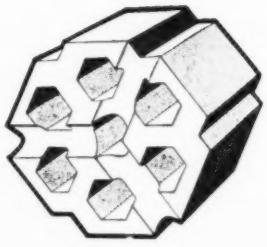
- Greater resistance to attack of iron and slag than any other refractory.
- Low after-contraction and increased cooling efficiency.
- No deformation under a load of two tons to the square inch at temperature of 1471 C.
- Cold crushing strength about four times that of an ordinary firebrick.

has supplied almost 200 Blast Furnace Linings throughout the world

CARBLOX

for the WELL-WALL, BOSH AND HEARTH

CARBLOX LIMITED, STORRS BRIDGE WORKS, LOXLEY
Near SHEFFIELD. Telephone SHEFFIELD 343844 (5 lines)



CARBLOX LIMITED now offer the TEMCO pattern chequer brick manufactured by our parent company, Thomas Marshall & Co. (Loxley) Ltd. This new brick has an effective brick mass of 99%—much higher than any other type of chequer. Details sent on request.

one of the MARSHALL REFRACTORIES GROUP of Companies

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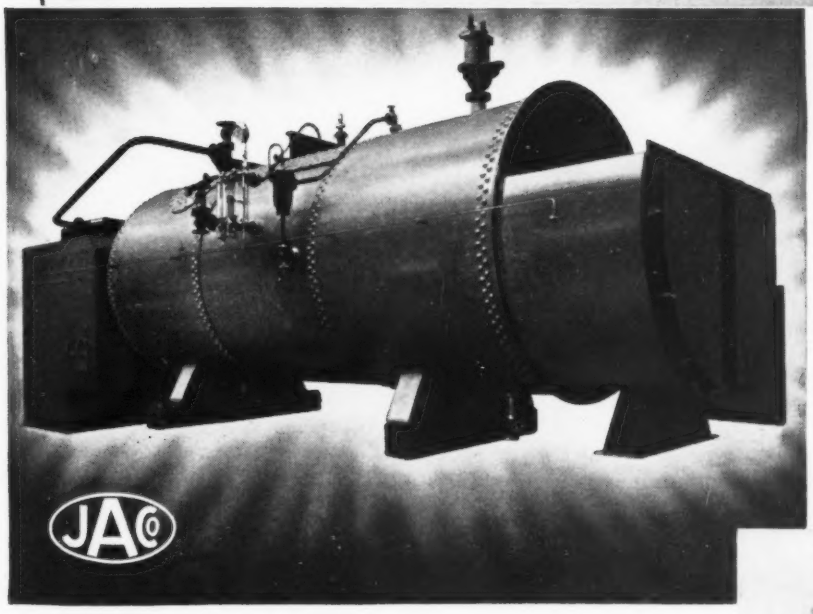
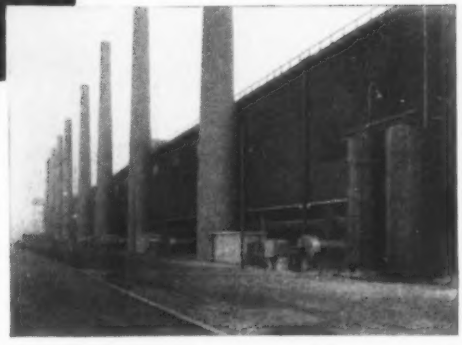
JOSEPH ADAMSON
Waste Heat Boilers

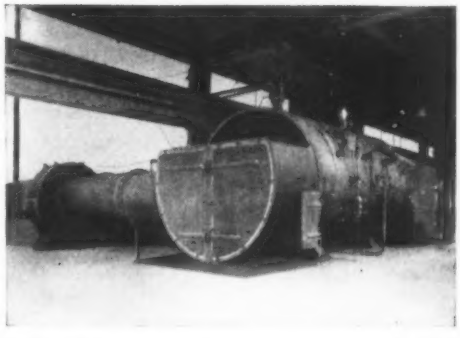


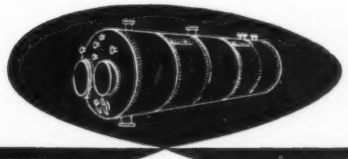


The Joseph Adamson Waste Heat Boiler is designed to make efficient use of the waste gases leaving open-hearth furnaces, reheating furnaces, soaking pits, gas retorts, etc.

The straight-through fire tubes have a high ratio of length to bore, giving about 90% tube efficiency and providing a large area of heating surface in a comparatively small space. Brickwork setting is not required and air infiltration is thus avoided.

A feature of Joseph Adamson Waste Heat Boilers is that a special cleaning device can be provided in the outlet chamber to allow the tubes to be cleaned while the boiler is at work.





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P. O. BOX 4 · HYDE · CHESHIRE

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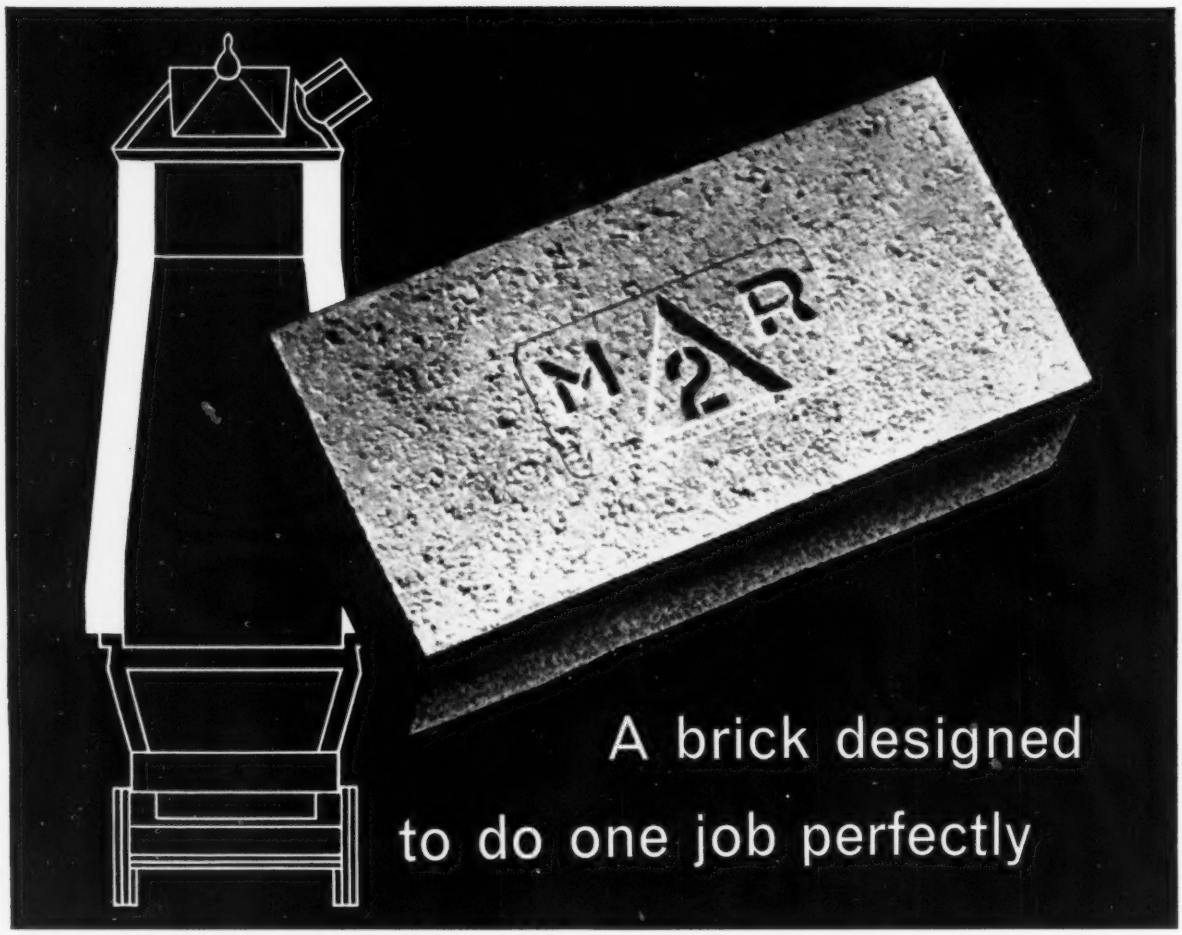
The Horsehay Company Ltd., Wellington, Shropshire

THE ADAMSON GROUP

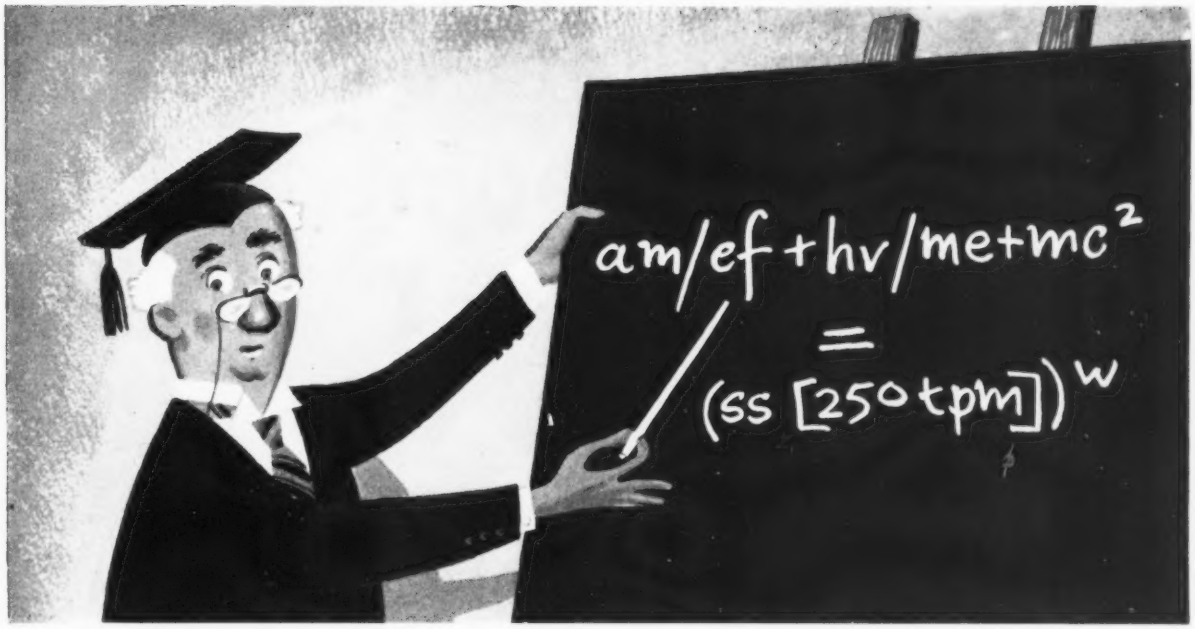
JA.11



This is the M.R.2 Blast Furnace refractory – a very special brick indeed. It was developed for one application – the lining of Blast Furnaces operating on lean ores – with 100% sinter – and driven hard. M.R.2 is an extremely hard, low porosity refractory to enable it to resist the abrasive effect of the sinter. It is completely unaffected by carbon monoxide and is manufactured from very carefully selected raw materials prepared and moulded under the most stringent control with a final kilning at temperatures of the order of 1600° C to ensure complete volume stability at normal Blast Furnace operating temperatures. This is a brick with a narrow market, but it is typical of the way the Chemists, Physicists and Engineers at Neston look upon the making of refractories – as a branch of precise chemical engineering. Amongst the other things they make with equal care are M.R.1 and M.R.60 bricks and special shapes; low-heat storage insulating refractories M.I.28, and the whole range of Tri-Mor Mouldables and Castables for Monolithic linings which are having such a profound effect on all classes of furnace design.

MORGAN Refractories Ltd

MORGAN REFRACTORIES LTD · NESTON WIRRAL CHESHIRE · TELEPHONE: NESTON 1406



"Who can simplify this equation?"

"Oh sir, please sir, me sir. You can say 'Willans = Special Steels'."

"Correct, Fishberry. Explain."

"Well sir, air melting electric furnaces plus high vacuum melting equipment plus lots and lots of metallurgical control equals special steels at 250 tons per month, all to the power of Willans. Isn't that right sir?"

"Absolutely right, boy. Go to the top of the class."

"Oh sir! Thank you sir. Same as Willans are sir."

Willans in a nutshell

Specialists in special steels. All types. 250 tons per month. Melting stock, ingots, billets, bars—standards or to your specification. Delivery?—quick Quality?—excellent. A.I.D., A.R.B., D.I. Arm? of course.

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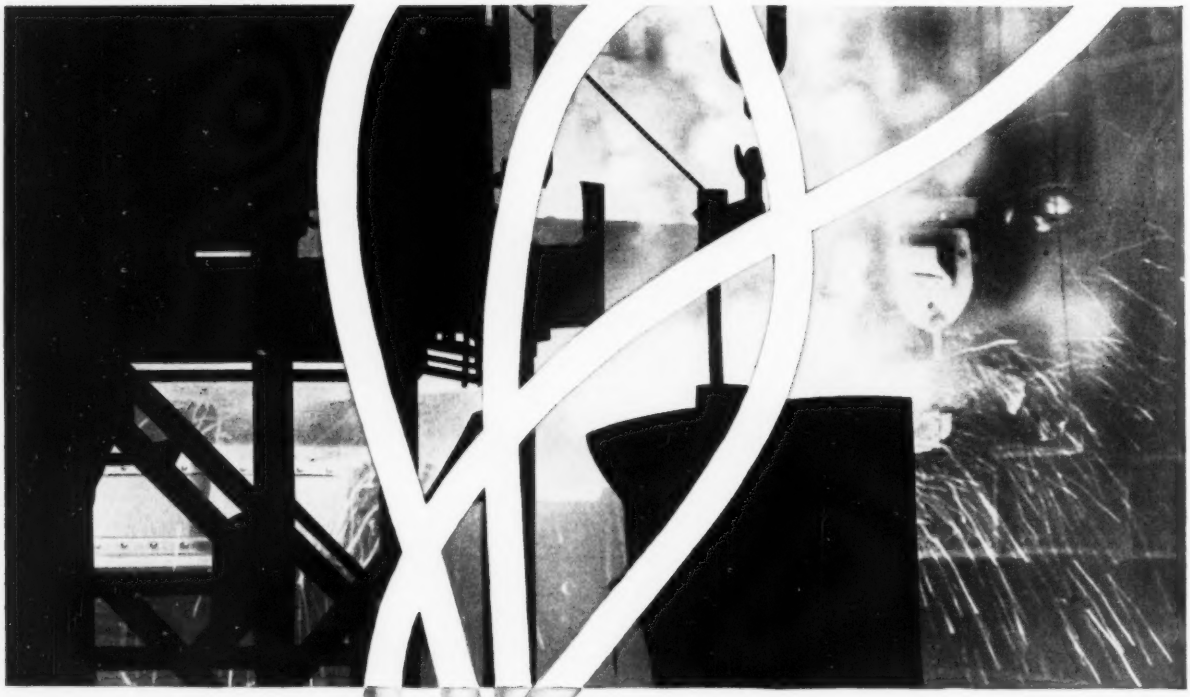

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BRITISH INSULATED CALLENDER'S CABLES LTD

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Hot gases billowing into the air . . . furnaces searing the surroundings . . . molten metals pouring from crucibles . . . conditions such as these are certain indications of the need for SILASTOMER* insulated cables.

Providing continuous long term operation in ambient temperatures up to 200 C, cables insulated with SILASTOMER silicone rubber are being specified more and more for complex industrial installations. They are resistant to low pressure steam, water, weathering and many chemicals and will withstand corona discharge. Glass braided silicone rubber cables will continue to function efficiently through and after the outbreak of fire.

These are the reasons why, in 1956, the Admiralty decided to use silicone insulated cables in all new ships of the Royal Navy and why this insulation was chosen for the cables in such important installations as the House of Commons. In many domestic appliances, too, SILASTOMER insulation is used.

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* *Silastomer is the registered trade name of a comprehensive range of silicone rubbers manufactured and marketed by*

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MSR 5

GWB

DEMAG

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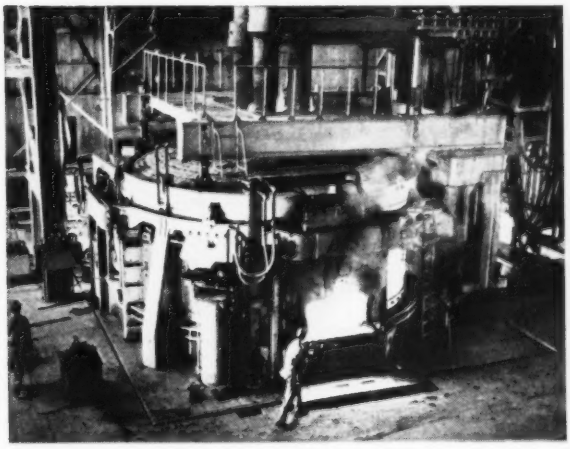
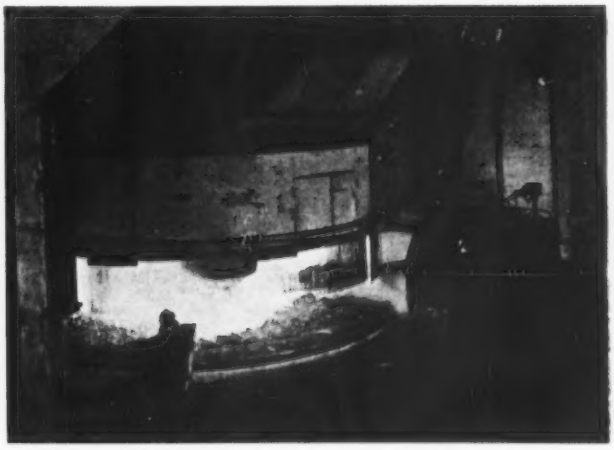
in capacities from 250 lbs to 200 tons

Technical improvements evolved over many years with the installation of over 2,800 units are incorporated in the British built Arc Furnaces of either Demag or Lectromelt design now being offered by G.W.B. As a result of the present agreements between the three companies there is no restriction to one particular design. When you discuss Arc Melting Furnaces with G.W.B. the most suitable furnace for your production programme and shop layout will be suggested from the wide range of designs available. Let G.W.B. advise you on your steel melting problems.

Lectromelt 36,000 kVA Steel Melting Arc Furnace with 24'0" diameter shell



Demag Submerged Arc Ferro-Silicon Smelting Furnace



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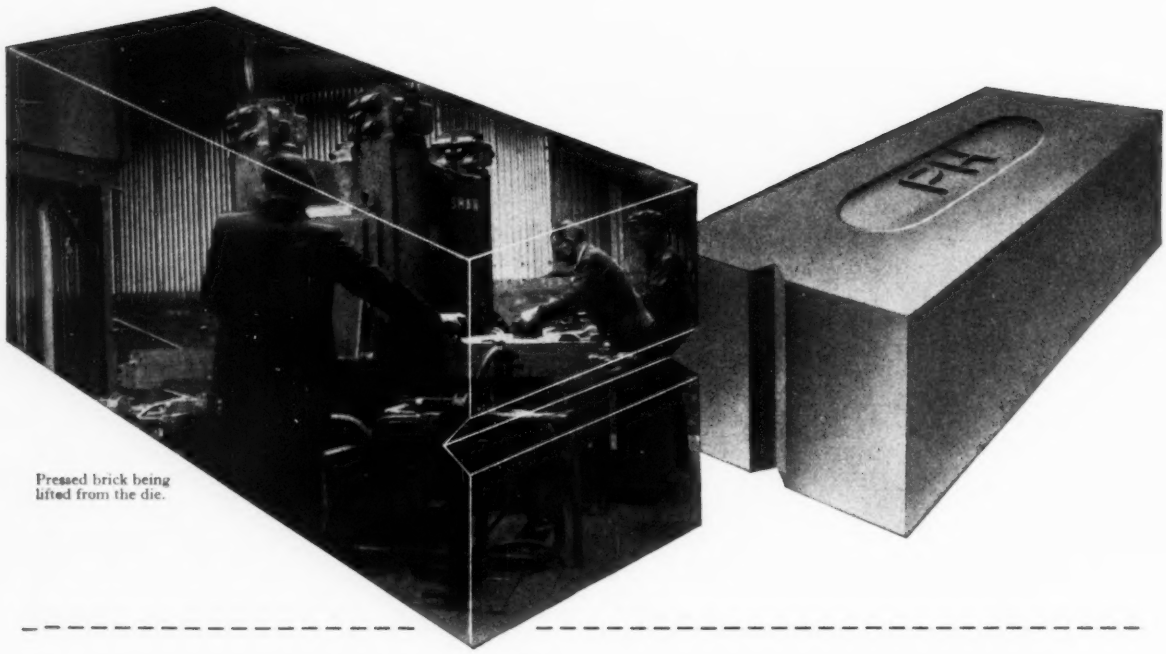


Pressed brick being lifted from the die.

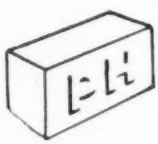
PRESSING PROBLEM SOLVED

Pickford Holland install the latest hydraulic presses for standard and special shapes

Refractory bricks today must be absolutely accurate in size and shape. These qualities, combined with unerring consistency in texture and performance are achieved by Pickford Holland through the medium of the most modern plant and equipment.

In Pickford Holland works, the very latest crushing, grinding and mixing plant, powerful hydraulic presses and continuous tunnel firing kilns have been and are being installed. Rigid control of the various processes is strictly observed, and the finished bricks are carefully inspected and tested before being despatched to the consumer.

More and more Pickford Holland refractory bricks are being supplied to steel and other industries throughout the world and the demand still grows. This surely points to the success of this policy of plant modernisation and is a tribute to the lasting service that these bricks give.



PICKFORD HOLLAND *Refractory Bricks*

Consistent in Size, Shape, Texture and Performance

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Stelvetite-plastic bonded to steel-has put a new face on Baldwin and Francis Switchgear Panels

SOMETHING NEW IN STEEL Until recently steel always needed periodic repainting. But not any more. Stelvetite even arrives with a finished surface in the colour you choose. A surface finish which lasts for ever. Stelvetite's permanent P.V.C. surface resists scratches, acids, detergents and time. Thus, in all manner of steel fabrication, Stelvetite saves on expensive surfacing processes. **It can be worked and welded as steel**, comes in a wide range of plain or embossed surfaces and is used to fabricate, among other things, lifts, doors, car panels, partitioning, furniture, kitchen equipment, walls and cladding—all of them colourful and permanent. Investigate Stelvetite. It may well save you a small fortune, or a large one.

Stelvetite

Plastic bonded to Steel

All enquiries about Baldwin & Francis Switchgear Panels should be made to Baldwin & Francis Ltd., Eyre St., Sheffield.

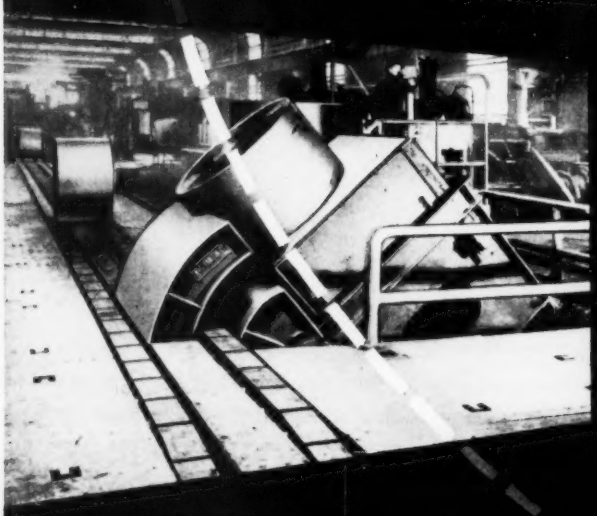
STELVETITE
made by John Summers and Sons Ltd. who produce over 52,000 miles of sheet steel every year. Write to us at Dept.J.S. Shotton, Chester, for full information.

PANTIN

heavy–duty handling systems

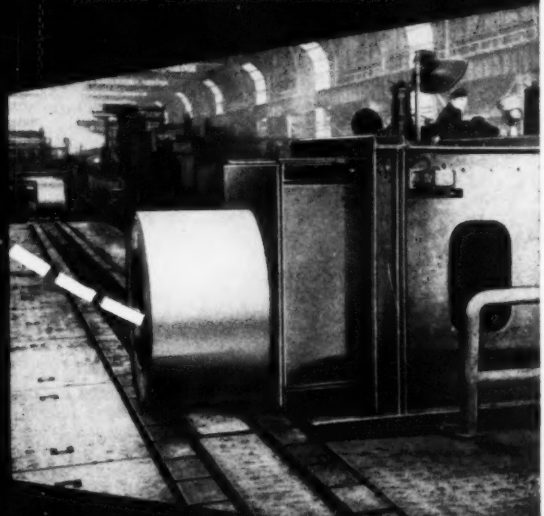
Pantin design and manufacture heavy duty mechanical handling plant for the Iron and Steel Industry.

This 'Upender', for example, was made to simplify and expedite the handling of coiled steel. With the utmost ease it takes coils up to 15 tons (max. dimensions 6′ diam. × 6′ wide) and lays them on a Pantin Pallet Conveyor for movement to the next station.



Pantin Handling Equipment covers every requirement, including upending and downending, tilting, hoisting and conveying of coils and sheets.

We are always pleased to discuss, advise and co-operate on the design of handling systems and shall be glad to send you details of Pantin Conveyors and Handling Equipment. Please write for illustrated brochure.



W & C PANTIN LTD CENTRE DRIVE EPPING ESSEX *Telephone EPPING 2271-4*

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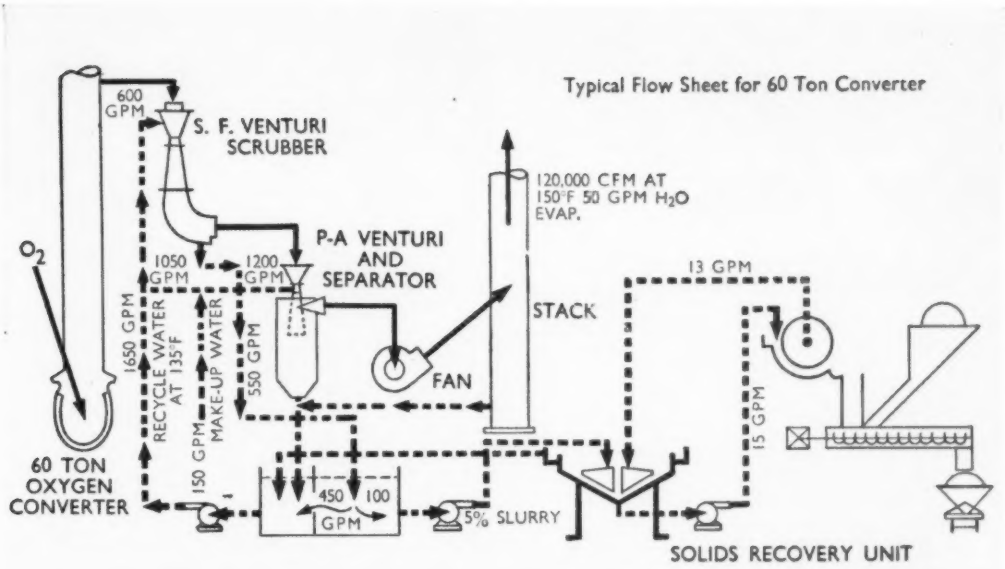

six converter installations prove

The recent installation of Chemico Venturi Gas Scrubbers at a major steel plant in Canada marks the sixth time Venturi Gas Scrubbers have been used to prevent an extremely undesirable source of air pollution—Iron Oxide Dust. Chemico Venturi Scrubbers maintain leadership in the world's steel industries because they offer wet scrubbing which allows non-explosive collection, efficiencies above 99% and extremely low maintenance. In addition no critical controls are required to maintain efficiency and the handling of dust is simplified by recovery in a dry form. Chemico Gas Scrubbers are ideally suited for Open Hearth Furnaces, Cupolas, Scarfing operations, Sintering operations, and Electric Furnaces. For further information and a copy of a brochure giving full particulars, contact the Chemico Gas Scrubber Division:

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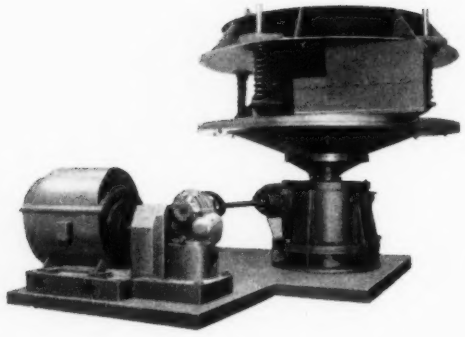
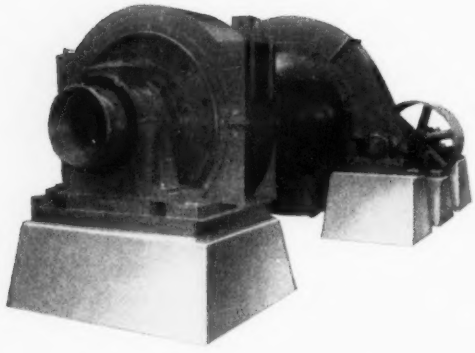
A SUBSIDIARY OF CHEMICAL CONSTRUCTION CORPORATION, NEW YORK, U.S.A.

Newells Modern Sinter Plant Machinery.....



FEED TABLES FOR

Accurately proportioning iron ore fines, crushed coke, flue dust, etc. Built in several sizes to suit customers silos and output requirements.



PATENT ROD MILLS FOR

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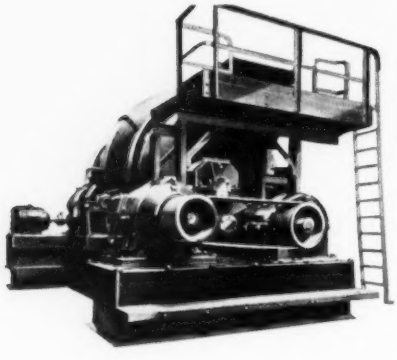
ROTATING DRUM TYPE PELLETISER + CONDITIONER FOR

Sinter materials, sizes and designs to meet individual requirement.



PATENTED ROTATING DRUM + MULTI-SCROLL MIXER FOR

Thoroughly mixing iron ore fines of varying densities and moisture contents, coke, breeze, flue dust and scale, etc., for mixed feed to sinter strands. Designs for outputs up to 500 tons per hour.

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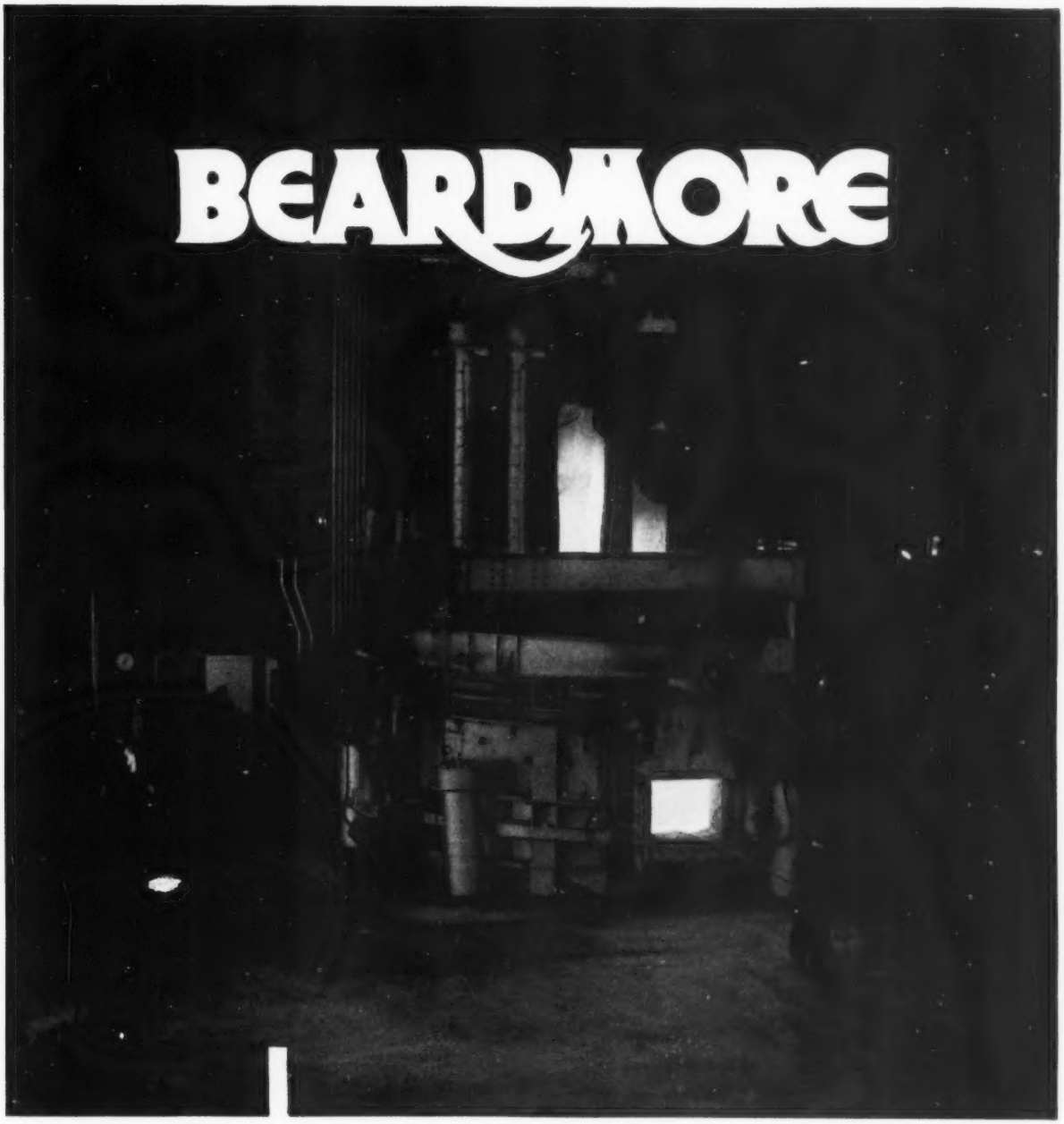
Ernest Newell & Co. Ltd., MISTERTON VIA DONCASTER.



Among the latest developments at Parkhead Steelworks, Glasgow is the 80-ton Electric Arc Melting Furnace shown above.

Forgings and Castings up to 150 tons in Carbon and Alloy steels, including Boiler Drums, Forged Steel Fully Hardened Work Rolls, Forged Steel Solid and Composite Back-up Rolls, Heavy General Engineering Plant and complete machining facilities.

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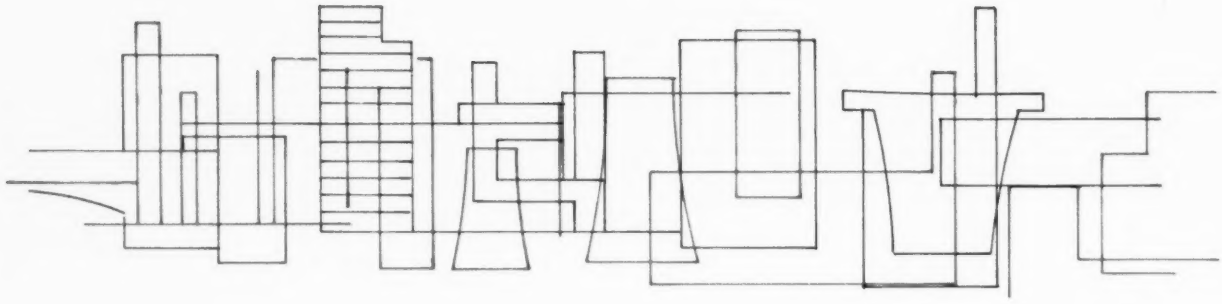
The Colville Group of Companies



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In Scotland, Colvilles are engaged on a vast development programme. By 1963 ingot capacity will be raised to 3.3 million tons per annum, and the Group will produce in their modern mills the full range of steel products—heavy and light plates, sheets and strip. Heavy and light sections, bars and broad flange beams.

THE COLVILLE GROUP OF COMPANIES

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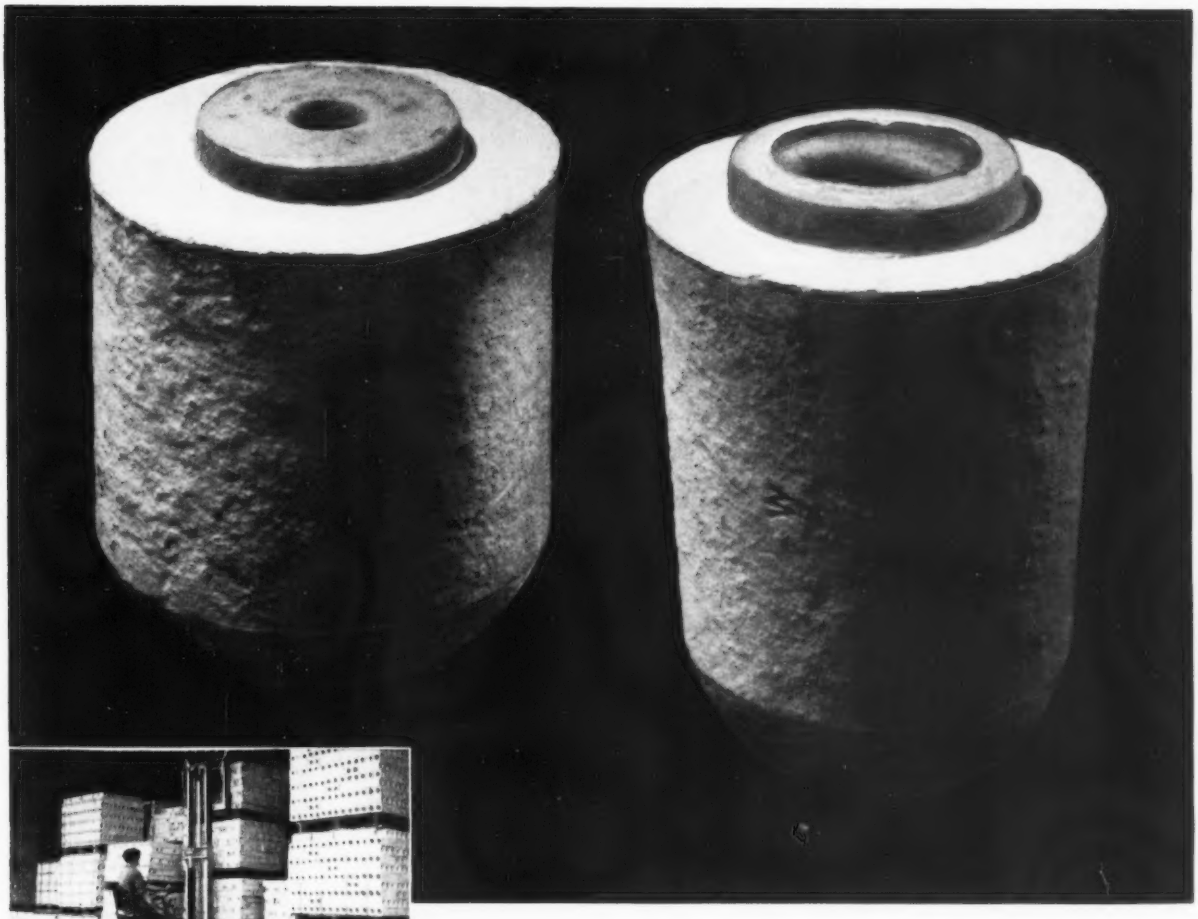
Arresting Refractories



DRY STORAGE UNTIL DESPATCH
Wet refractories can cause trouble, so we keep our stocks under cover until you're ready for them.

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NOZZLES · STOPPERS · SLEEVES
TRUMPET GUIDES · TRUMPET BELLS
CENTRE & RUNNER BRICKS
INGOT FEEDER TILES

Arresting in function, for these are stoppers. Arresting in quality of manufacture too, like all casting pit refractories made by Wraggs of Sheffield.

Their family of products contains the breeding of years of specialisation, for Wraggs were pioneers in casting pit refractory manufacture. Today, they are one of industry's largest suppliers...

Wraggs of Sheffield *for reliable casting pit refractories*

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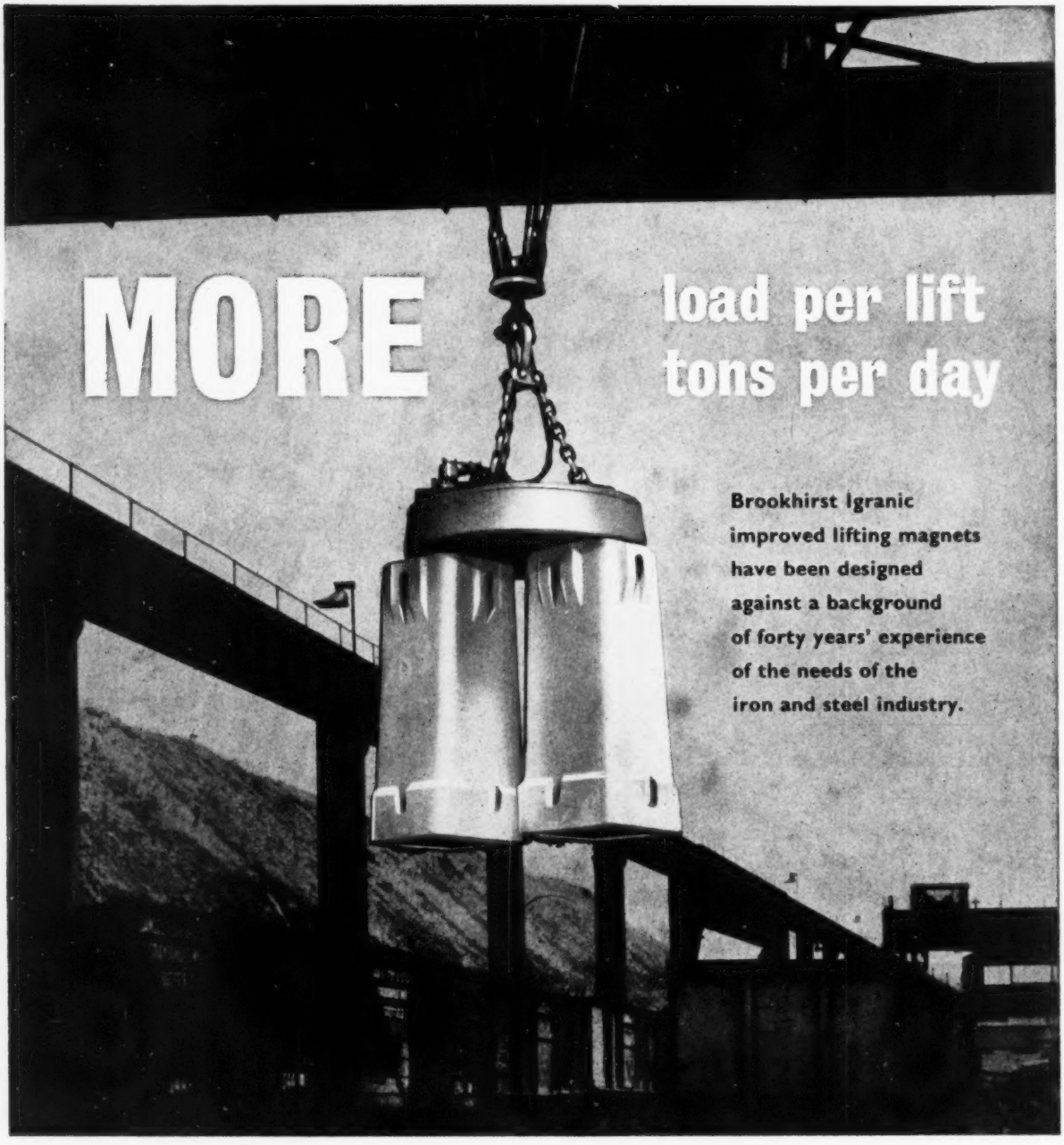

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BHI
Metal Industries Group.

Makers of Britain's most rugged and dependable lifting magnets—rectangular, circular, bi-polar, multi-polar—a range of over thirty.

BI.21

MAKING LARGE TIMKEN BEARINGS

This illustration, of part of the assembly department at our Daventry works, shows a variety of large bearings. The one shown partly in section in blue (full size) is 25½ ins. bore, 40½ ins. outside diameter, 22½ ins. wide. We have supplied this bearing for the past 21 years for the back-up rolls of a wide strip mill.

THE demand for large Timken tapered roller bearings has been growing steadily for over 30 years. To help to meet this demand, it was decided six years ago to build a new factory at Daventry for the manufacture of large bearings only, and this factory was very quickly in full operation.

Some Timken bearings exceed 7 feet in diameter, others weigh as much as 4½ tons.

British Timken, Duston, Northampton, Division of The Timken Roller Bearing Company. Timken bearings manufactured in England, Australia, Brazil, Canada, France and U.S.A.

TIMKEN®

REGISTERED TRADE-MARK

tapered roller bearings

STEETLEY SD*

SILICA

ROOF BRICKS

by OUGHTIBRIDGE

* S.B. denotes and means — SUPER DUTY

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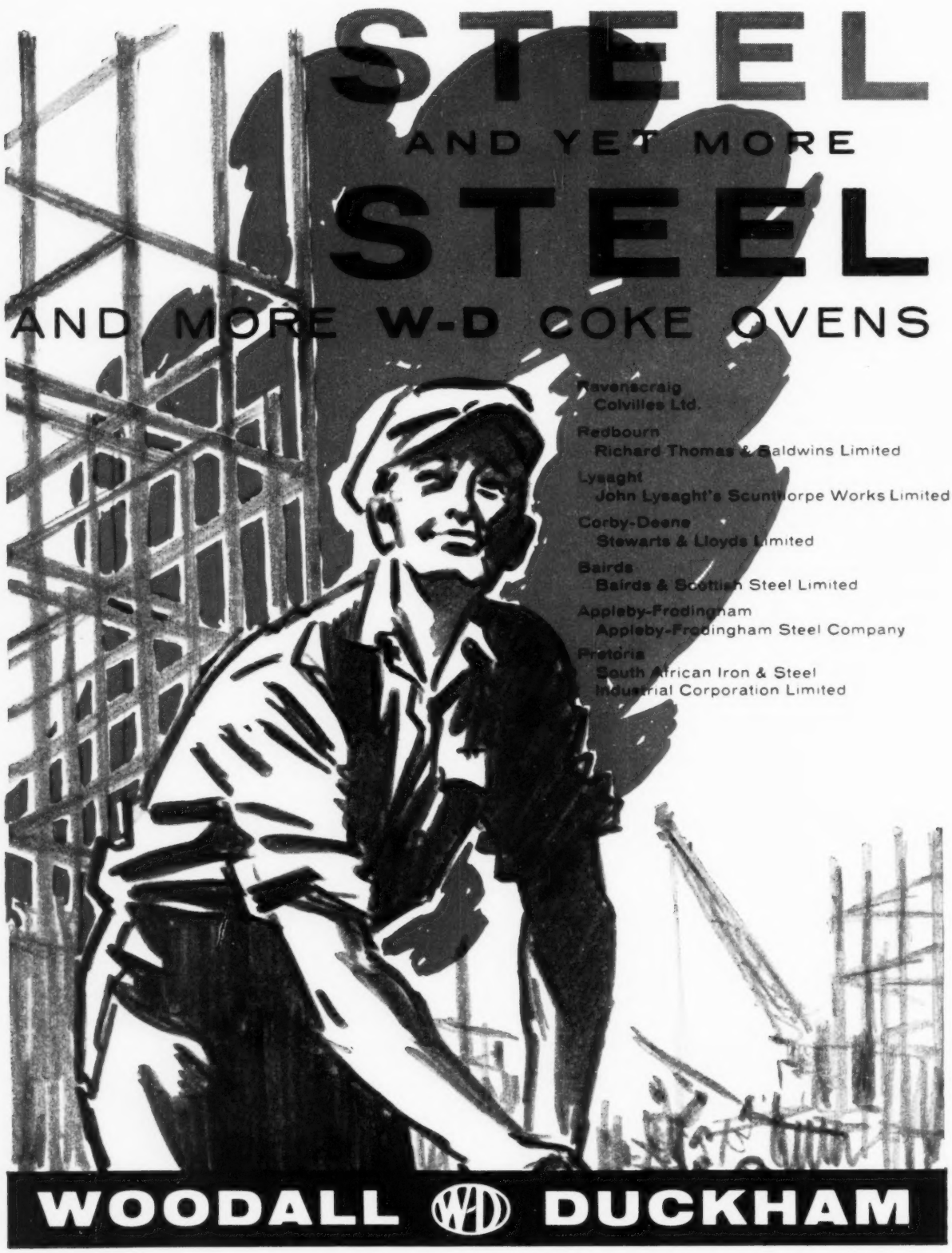

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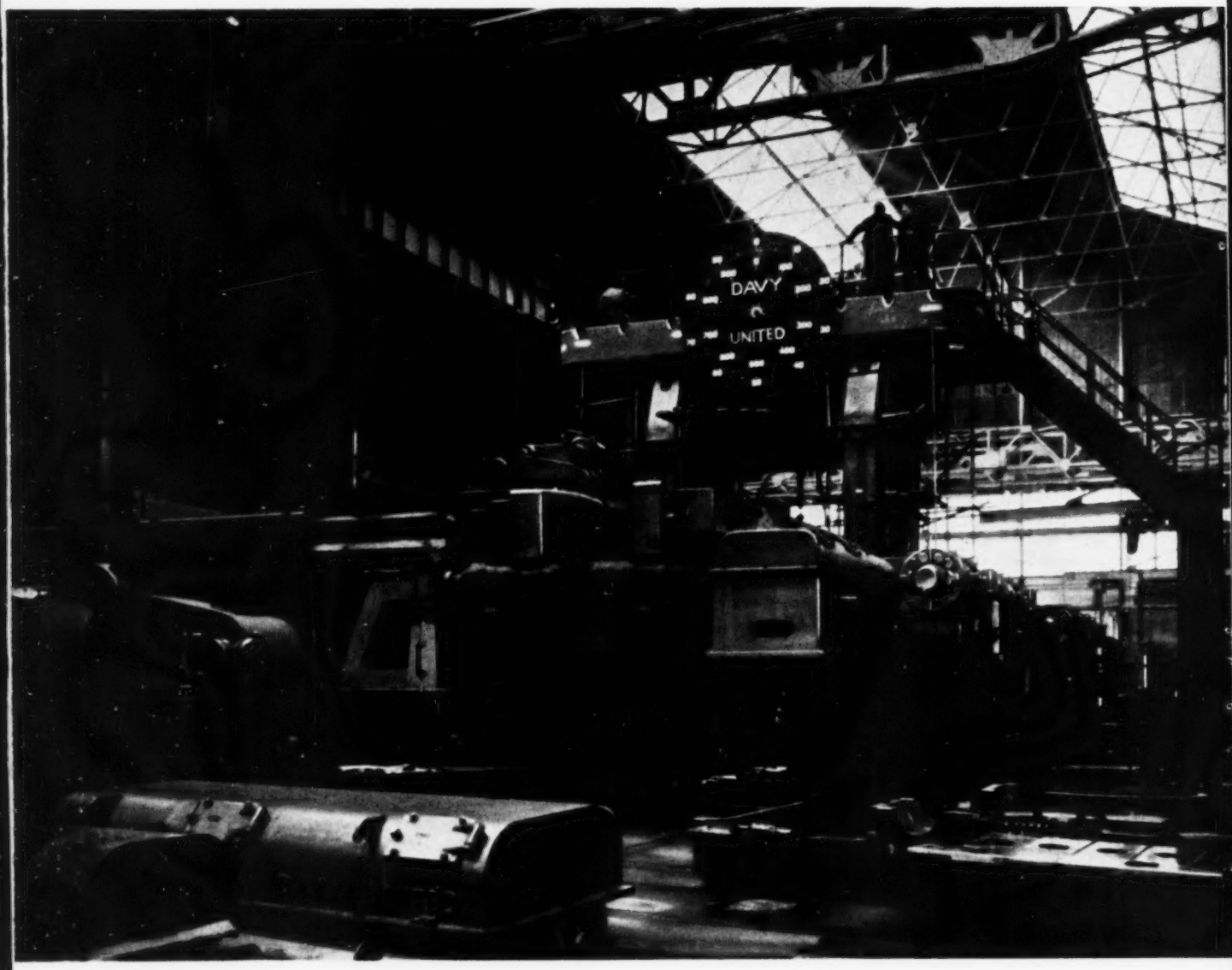
THE IRON AND STEEL INSTITUTE
4 Grosvenor Gardens London SW1

42″ BLOOMING MILL FOR THE NEW STEELWORKS AT DURGAPUR

in West Bengal being constructed by ISCON, photographed in course of erection in Davy-United's Darnall Works. As a member of ISCON Davy-United are responsible for over a quarter of this new Indian Steelworks, including all the rolling mills, the wheel and axle plant, the central engineering maintenance shops and the iron and steel foundry. The engineering and supply of all the 75,000 tons of machinery involved is being co-ordinated by the Davy-United Construction Division.



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W. F. CARTWRIGHT, D.L., J.P., M.I.Mech.E.

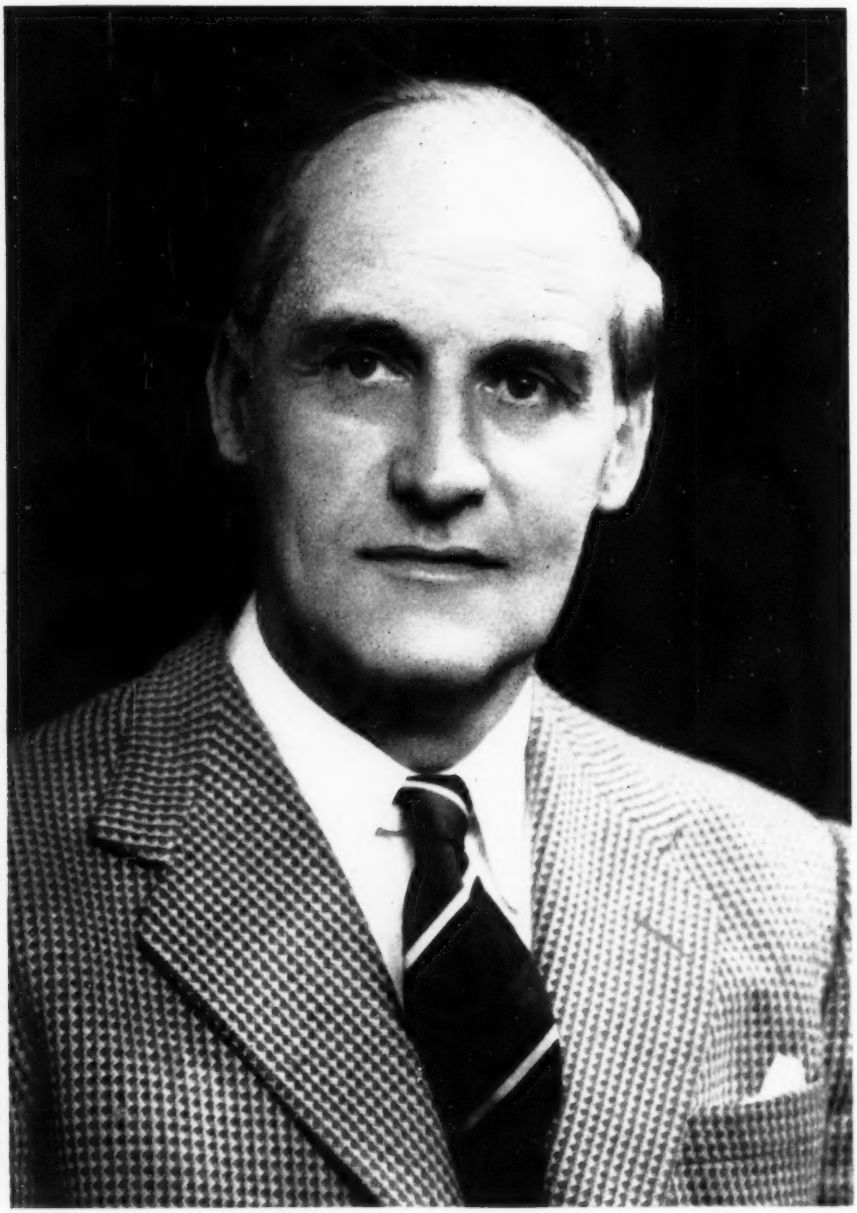
WILLIAM FREDERICK CARTWRIGHT was born in 1906 and educated at Dragon School, Oxford, and at Rugby. His technical training began in 1925, when he entered the Swindon works of the Great Western Railway as chief mechanical engineer's pupil; three years later he transferred to the drawing office.

He joined Guest Keen and Nettlefolds Ltd in 1928 at their Dowlais works, where he remained until late 1930, then spent a year studying Continental practice at steelworks in Germany, Luxembourg, and France. Mr Cartwright returned to the United Kingdom at the end of 1931 to take up the position of assistant works manager at the Port Talbot works of Guest Keen Baldwins Iron and Steel Co. Ltd; four years later he was appointed technical assistant to the managing director, a post he held until 1940. During this period he was intimately concerned with the reconstruction and enlargement of the company's East Moors works. He was appointed chief engineer in 1940, and at the same time was elected to the board of the company. Three years later he became general manager of the Margam and Port Talbot works.

When the Steel Company of Wales Ltd was formed in 1947, Mr Cartwright was elected a director and became general manager of the steel division. It was under his leadership that the development of the Abbey works at Port Talbot took place. In 1954 he became assistant managing director of the company.

Mr Cartwright is a member of many technical and scientific organizations, including the Institution of Mechanical Engineers (former member of council), the South Wales Institute of Engineers (member of council), the British Iron and Steel Federation (member of council), the British Coke Research Association (member of council), the British Iron and Steel Research Association (member of council), and the Institute of Fuel (Fellow). He is a member of the governing bodies of a number of educational establishments, including University College, Swansea, and the University College of South Wales and Monmouthshire, Cardiff. Mr Cartwright is also a Deputy Lieutenant of the County of Glamorgan and a Justice of the Peace.

When the Iron and Steel Engineers Group was formed in 1946, Mr Cartwright, who joined The Iron and Steel Institute in 1936, became first Chairman of the Engineering Committee, and his drive and enthusiasm did much to establish the success of the Group. He was elected a Member of Council in 1946, and became a Vice-President nine years later. In 1958 he received the Bessemer Gold Medal, and this year he has been awarded the Federico Giolitti Steel Medal by the Associazione Italiana di Metallurgía. Mr Cartwright has been elected President of the Institute for 1960–61.



W. F. Cartwright, D.L., J.P., M.I.Mech.E.

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PRESIDENTIAL ADDRESS

Production control in an integrated iron- and steelworks

W. F. Cartwright, D.L., J.P.

I was first made aware of the problems of production control in an integrated iron- and steelworks when working in Germany in 1930. At that time, almost all the large German steelworks were already highly integrated, so that the operations of one department influenced another.

Demand was at a very low level, and at the Hoesch steelworks the company adopted a policy of working slowly throughout the week in order to spread the problems connected with the supply of pig iron and coke-oven and blast-furnace gas: at the August Thyssen-Hütte works, however, they adopted a policy of running at full output for three days and then closing all the furnaces down, with the exception of a small number of open-hearths, which put ingots in stock for recovery when the mill started up again. Such irregular working highlighted the problem of production control.

At that time, probably the most elaborate form of control in German iron- and steelworks was the gas control. Every cubic foot of blast-furnace and coke-oven gas was used, but this very integration produced its own problems. As the open-hearths were fired by coke-oven gas, it was necessary to manufacture coke. If coke was manufactured, it was necessary to manufacture pig iron. The normal method of operation would have been to use most of this pig iron in basic Bessemer converters, but the demand for steel was mainly in OH grades. The result was that the works were burning coke in the blast-furnaces to make coke-oven gas, and using the pig iron in the converters, only to pass the resultant blown metal to the open-hearth to duplex it.

The gas control rooms in Germany in 1930 were already very advanced, and, with the sole exception perhaps of the introduction of the panels, there has been little progress since then in this particular field. A sheet used at Hoesch in 1931 made up from the records of the gas control room (Table I) shows the lengths to which they would go to check the various records one with another. It is doubtful whether even today many British steelworks take the trouble to check that the blast volumes they book to the blast-furnaces tally when balanced against the quantity of carbon in the blast-furnace gas, flue dust, and pig iron. It will be noted from the calculation that they have assumed that nitrogen blown in at the bottom of the furnace leaves at the top. Checks on the Port Talbot furnaces do not always bear this out, as is shown in Table II; the same sheet calculated for a week at Port Talbot shows that, whereas very good agreement of theoretical and actual blast requirements are obtained for the nos. 2, 4, and 5 furnaces, the nos. 1 and 3 furnace figures are not in agreement. Such discrepancies merit continued investigation since reasons are not usually apparent.

On returning to the integrated iron- and steelworks at Port Talbot, I found that very little attempt was being made at that time in the UK to control production in the way it was on the Continent. However, in the next four or five years, rapid progress took place, and by 1935 all large iron- and steelworks in the UK had also established full gas control rooms.

It occurred to me shortly before the war that possibly all forms of energy should be controlled from one room, as very often, if there is a shortage of blast-furnace gas, the question of whether to burn more coal to keep up the generation or to purchase more electricity from outside is one that can only be answered by somebody who knows the full facts of the availability of gas and also those of electrical maximum demand. However, such an idea was not found acceptable, and to this date at Port Talbot, the gas control and the power-station management remain separate. In at least one works, however, that of Geneva in the USA, the whole control of all energy, whether from gas, fuel oil, coal, or electricity purchased from outside, is in one large control room. In any new iron- and steelworks, I feel this arrangement should be adopted.

During the large-scale expansion plan for Port

TABLE I Calculation showing blast theoretically required and actually used (Hoesch Werke AG, 6 September 1931)

	Blast-furnace I tons	C%	tons C	Blast-furnace III tons	C%	tons C	Blast-furnace IV tons	C%	tons C	Total
Total coke	469		403·3	405	86	348·3	634		545·2	1508 tons coke
Ore	742	1·94	14·4	580	2·11	12·3	995	1·75	18·8	2317 tons ore
Total 'A' of carbon			417·7			360·6			564	
Flue dust	25	5·2	1·3	20	5·0	1·0	25	5·2	1·3	70 tons flue dust
Pig iron	370	3·45	12·8	320	4·0	12·8	590	2·1	12·4	1280 tons iron
Total 'B' of carbon			14·1			13·8			13·7	
'A'–'B' carbon	403·6 tons			346·8 tons		550·3 tons				
Average gas analysis:										
CO_2	5·5			7·8			7·0			
CO	35·5			30·6			33·9			
	41·0% = 21·976 kg Carbon in 100 m³ dry gas			38·4% = 20·584 kg Carbon in 100 m³			40·9% = 21·922 kg Carbon in 100 m³			
H	2·3			2·4			2·6			
N	56			59·2			56·5			

Gas output, 1000 m³		Gas output/ton coke	Theoretical blast required, 1000 m³	Theoretical blast per ton of coke	Actual blast consumed, 1000 m³	Actual blast per ton of coke
Furnace I	1835*	3·99	1318†	2·82	1405	3·00
Furnace III	1685	4·16	1262	3·12	1262	3·12
Furnace IV	2475	3·90	1770	2·79	1884	2·98
Total	5995	3·975	4350		4551	

* To obtain gas output

$$\frac{403600}{21{\cdot}976} = 183500\ m^3 \times 10 = 1835\ m^3 \times 10^3$$

† To obtain theoretical blast requirement

$$\frac{1835 \times 0{\cdot}56}{0{\cdot}79} = 1318$$

Talbot in 1947, it became clear that management of other departments besides fuel would require more formal control. Among others, a control known as the 'ingot controller' was instituted. A study was made at Cardiff works of the way in which in practice the ordering of steel on the various OH furnaces, the berthing of the various-sized ingot moulds, and their arrival at the soaking pits was planned. At that time such work was in the hands of the soaking pit planner, who, knowing what orders he had on hand, issued instructions to the OH shop, but he had a relatively simple problem as he was only dealing with six OH furnaces in one shop. At Port Talbot, there were then 20 furnaces in three separate shops. Today we have four separate shops with 27 furnaces of varying size and type, but, perhaps even worse, we have no fewer than 18 sizes of ingot mould. Thus planning the movements of the ingot bogies with various ingot moulds becomes an extremely complicated operation.

In the paper 'Present methods of open-hearth furnace charging' by Diamond and Frankau,* in connexion with the control of such operations, there is developed a technique for following visually the

* E. L. Diamond and A. M. Frankau: *JISI*, 1949, **161**, 191–211.

TABLE II Calculations showing blast theoretically required and actually used (SCOW blast-furnaces for week ending 30 January 1960)

	Blast-furnace 1 tons	tons C	Blast-furnace 2 tons	tons C	Blast-furnace 3 tons	tons C	Blast-furnace 4 tons	tons C	Blast-furnace 5 tons	tons C	Total
Total coke	3780	3241	5091	4369	4088	3505	8139	6980	7883	6934	28981 tons coke
Ore and fluxes	10821	143	12747	293	10613	129	21141	316	23286	280	78608 tons of ore and fluxes
Total 'A' carbon		3384		4662		3634		7296		7214	
Flue dust	123	31	849	76	370	43	379	94	314	70	2035 tons flue dust
Pig iron	5531	222	5744	225	5592	235	11253	461	12275	507	40395 tons pig iron
Total 'B' carbon		253		301		278		555		577	
'A'–'B' carbon		3131		4361		3356		6741		6637	
Average gas analysis:											
CO_2	11·0		12·4		11·0		14·2		16·1		
CO	30·2		28·4		29·9		26·7		25·3		
CH_4	0·4		0·4		0·4		0·4		0·4		
	41·6% = 22·32 kg Carbon in 100 m³ dry gas		41·6% = 22·11 kg Carbon in 100 m³ dry gas		41·3% = 22·20 kg Carbon in 100 m³ dry gas		41·3% = 22·17 kg Carbon in 100 m³ dry gas		41·8% = 22·42 kg Carbon in 100 m³ dry gas		
H_2	1·8		2·3		2·6		2·4		2·4		
N_2	56·6		56·5		56·1		56·3		55·8		

Gas output, 1000 m³		Gas output/ton coke	Theoretical blast required, 1000 m³	Theoretical blast per ton of coke	Actual blast consumed, 1000 m³	Actual blast per ton of coke
Furnace No.1	14003	3·704	10010	2·648	11980	3·169
Furnace No.2	19698	3·869	14090	2·767	14570	2·861
Furnace No.3	15115	3·697	10730	2·624	13640	3·336
Furnace No.4	30418	3·737	21680	2·663	21820	2·680
Furnace No.5	29614	3·756	20920	2·653	21270	2·698
Total	108848		77430	2·671	83280	
Plant average		3·755		2·671		2·873

Units of weight and volume:
(i) The metric ton of 1000 kg is used
(ii) Gas volume measurement is referred to C. Metres at 0°C and 760 mm Hg pressure

movements of locomotives and trains on a diagram. When the Abbey open-hearth shop at Port Talbot was first being planned, a large model was made on which all operations could be followed visually, and it was, in fact, possible to reproduce the operation of the shop in every possible detail.

With the Diamond system, it was possible to follow the operation of any shop visually on paper; with small modifications, this system was adopted for ingot control, and ultimately for the control of the stage traffic charging the large Abbey open-hearth shop. Figure 1 shows part of a sheet which has actually been used in the ingot controller's tower, and Fig.2 illustrates more clearly how the system works.

It is interesting to note that when I visited the Krivoi Rog iron-ore mine in the Ukraine in 1955, they were employing this identical system, in the operation of the electric railway bringing all the ore cars from the face to the tipplers at the bottom of the shafts.

At Port Talbot, the ingot controller is in communication by direct line to the pitsides of all melting shops and to the soaking pit planner, and, as he is in a tower at the entrance to the stripper bay, he has visual command of the stripper bay and soaking pit area. From this tower the operation of locomotives arriving from the four melting shops and entering the stripper bay can be seen. However, the main control of the locomotives is by wireless to each of the five ingot locomotives; the controller can dial the number of the locomotive he requires, and that locomotive only will then answer. This system has now been developed to a high degree and operates extremely well. Figure 3 shows the layout of the ingot controller's office in the tower.

In the early stages of operation of the strip mill at Port Talbot, there were only three blast-furnaces. These were of 21 ft, 25 ft 9 in., and 25 ft 9 in. hearth dia. respectively, and their makes per day were not very different, but with the addition of a fourth furnace of 29 ft 9 in. dia. a new problem emerged, that of the control of the supply of hot metal to the various melting shops, and so a hot metal controller was appointed. His job was further complicated by the arrival of no.5 blast-furnace of 31 ft hearth dia., operating on a high percentage of sinter, and tapping into torpedo ladles of a different type from those used on the other four furnaces. Thus the iron controller now has the problem of dealing with five blast-furnaces with makes of about 5000, 7000, 7000, 11000, and 12000 tons per week. These furnaces tap into two different-sized ladles, one holding about 60 tons, and the other holding about 190 tons, and making two grades of pig iron, one with 0·35%P and one of 1·8%P.

There are three mixers in the Abbey shop, two of which are normally in commission, and two in the basic Bessemer shop, one normally in commission. There is no mixer operating in the two small shops at Port Talbot and Margam. Under certain circumstances the iron controller is faced with a decision as to whether to tell the blast-furnacemen they are going to have to slow down owing to shortage of ladles, or to pour molten metal into the iron granulating machine, in order to free a ladle to keep a furnace in operation. He is faced with demands, very often conflicting, for direct hot metal from the two old shops. A similar graphical record is used by the iron controller to show the location of the various ladles, whether they are full or empty, and this system is undoubtedly essential for the smooth working of so many different points of supply to so many different points of demand.

Another control which has been established is that of oxygen controller. Here is a somewhat different problem from that of the normal gas control. There is only one supplier of oxygen, although the plant consists of two separate units, one of 100 tons per day and the other of 200 tons per day, to which two further 200-tons per day plants are to be added. The main users of oxygen, in order of priority, are the basic Bessemer plant, the scarfer, and the OH shops. The oxygen controller has to exercise discipline over 24 OH furnaces, many of which may be requiring oxygen, when there is only enough available to blow one furnace.

This control is, at the moment, in the early stages of operation. No remote flow-indicating instruments are yet in operation, and control is entirely by telephone and pressure indication. Since the rate of consumption is frequently far above that of the rate of supply, receivers have been installed, and much calculation has been done to find out the number of receivers necessary to avoid blowing off to waste and yet avoid departments being short of oxygen when they require it.

Since the use of oxygen is always increasing, particularly with the development of basic bricks in the OH, a continued shortage is visualized for some time to come, making the job of oxygen controller a difficult one, and as yet no formalized control system has been developed. At the moment the oxygen control is carried out by the gas controller in the gas control room.

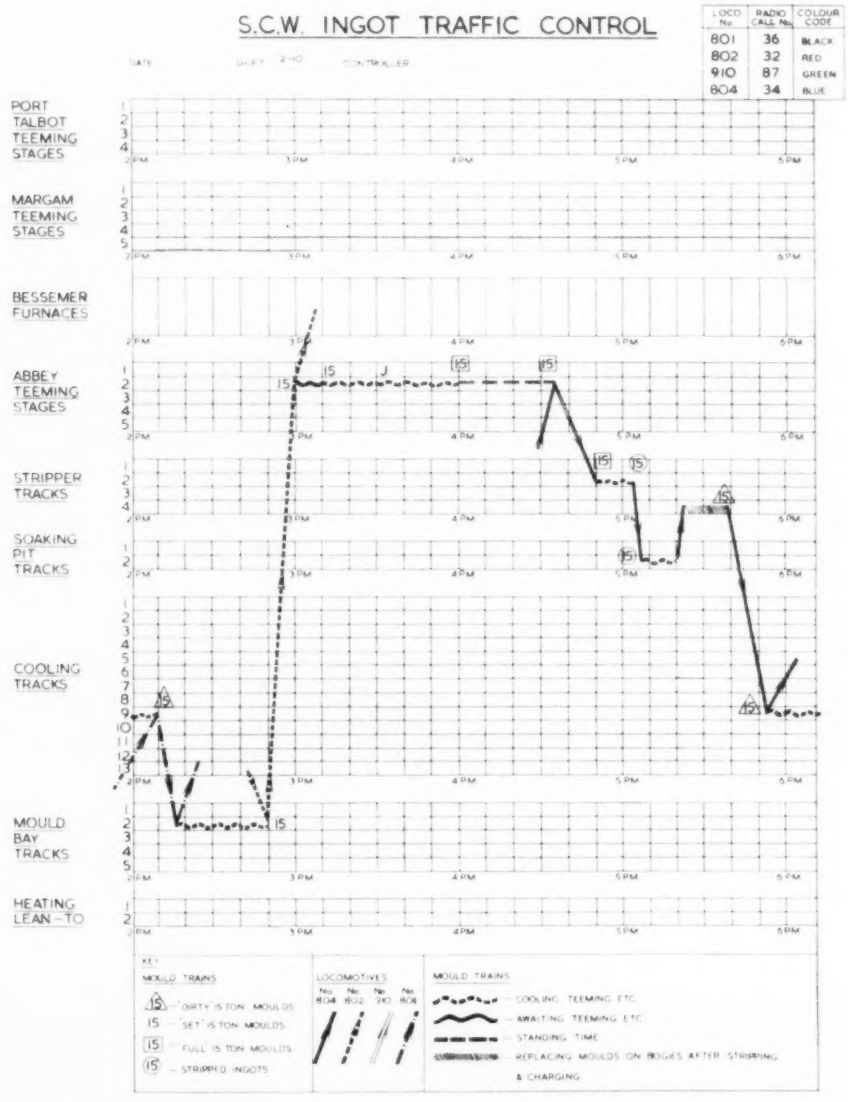
One of the most important production-control matters is that of stocks. It used to be said that the cheapest method of stocking coal was in 10-ton railway wagons, and there is no doubt that there is some truth in this observation if the period of stocking is to be a short one; however, control of the main raw material stocks (coking coal, coke, pig iron, scrap, and iron ore) is one of the chief headaches of any production-control department in a large iron-and steelworks. Inherently, coke ovens do not like being raised and lowered in production. If raising or lowering is carried out over a sufficiently long time, damage can be avoided, but coke ovens will unquestionably give of their best if kept at a steady rate of production. Blast-furnaces do not always work according to plan. Even the plans must include a re-line, and thus it is almost impossible to avoid a fluctuating coke stock, depending on the working of the blast-furnaces and the relining programme. The coking coal problem is not as simple as the steady rate of operations of the coke ovens would imply.

In the first place, the South Wales coalfield is made up of a very large number of pits; this is illustrated by the fact that in the first six months of 1959 the coke ovens at Port Talbot received 105 different grades of coal. Roughly they are divided into high, medium, or low volatile, and washed and unwashed, but the stocking problems of storing coals of widely different characteristics can be immense, and these problems are accentuated by the fact that every holiday brings a wide variation in the supply of coal. Strikes, shortage of railway wagons, and bad weather may also introduce separate problems.

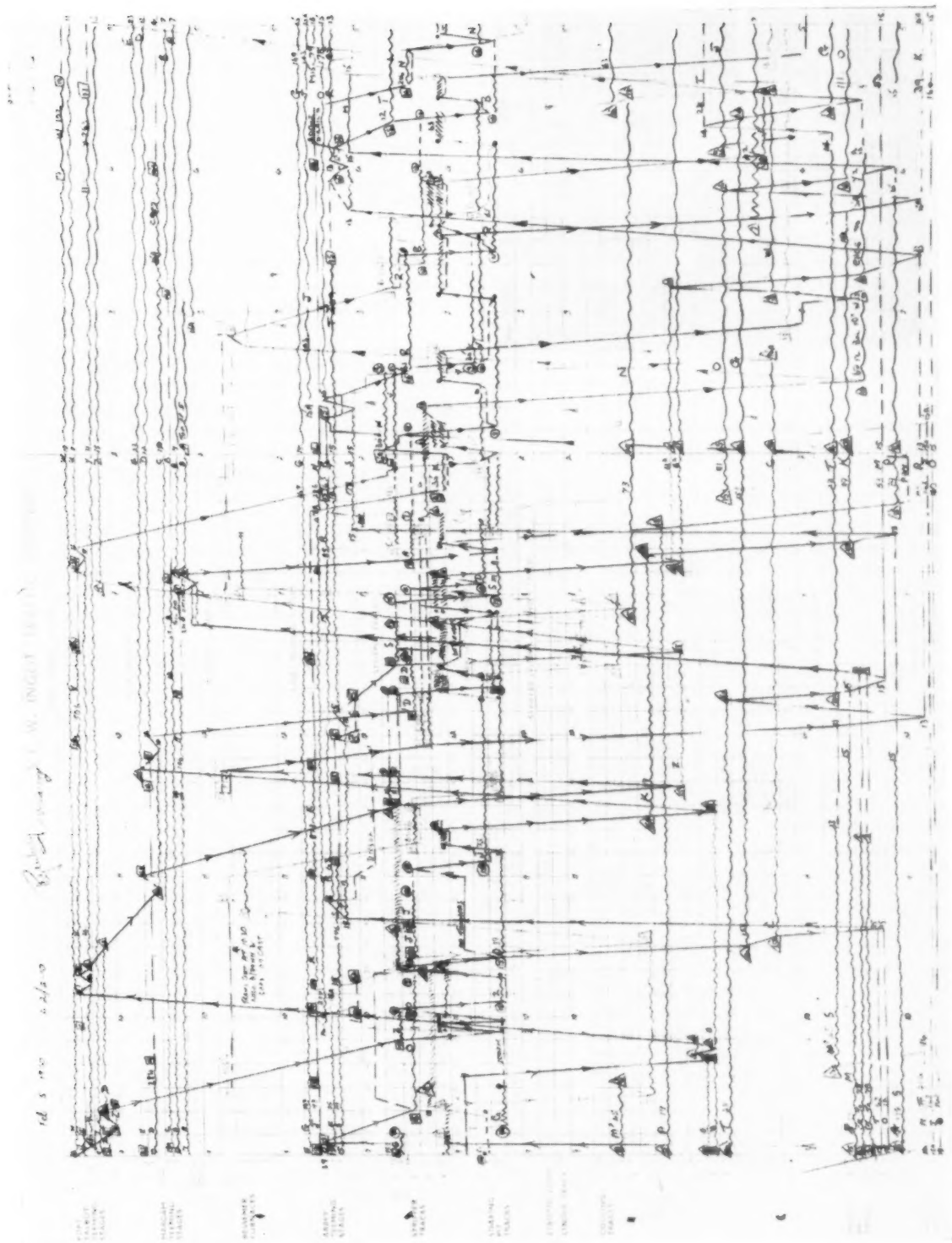
To control coke quality, there is no doubt that a

reduction in the number of coals would assist matters, for with two coke-oven plants, one with a washery and one without, and large variations in the rate of supply, whether to stock or to hold in wagons becomes a question of importance and one that is difficult of solution. Long-term planning is necessary to ensure that coals are always turned over, and yet that adequate stocks, which in the case of Port Talbot amount up to 100000 tons, are built up before each summer holiday in the coalfield. We have found that it is difficult to reduce the number of coals, which is important if our washing technique and therefore our coke quality are to improve, unless we have a considerable stock of coal always on hand ready to bridge any variations in the outputs of the various collieries. This requires a careful analysis of the savings that can be effected by carrying larger stocks to compare with the losses obviously incurred by double handling or standage charges.

It has been found that the picking up of any considerable quantity of stocked coke immediately results in a deterioration of blast-furnace performance, making it clear that it is essential to have not only a good method of stocking coke and recovering it, but also an adequate screening plant, which can screen stocked coke when recovered. In order to get good results from any coking plant over a period, it is necessary to have a long forward plan, taking into account colliery holidays, any planned stoppage of the plant such as Christmas, and relining of blast-furnaces, and this involves a proper coal stocking plant, with a method of keeping the various grades of coal separate; a proper coke stocking plant must be capable of receiving coke at the full rate of output of the coke-oven plant, and of recovering it and screening it at a high rate. Given these facilities, it should be possible to ensure that the interruptions in coke consumption due to blast-furnace relines, involving heavy stocks of coke, can be spread

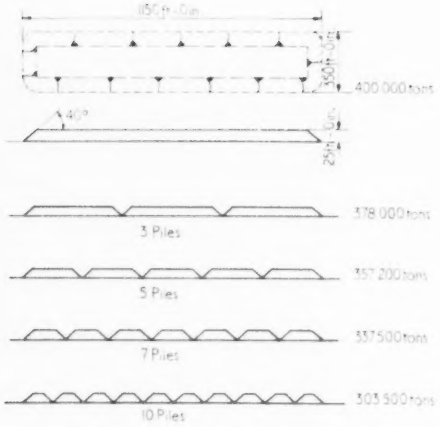


1 *Part of ingot controller's sheet*



2 *Fuller description of the system*

3 *Inside of tower*



4 *Illustration showing reduction of stocking capacity of a typical area with increase in number of ores stocked*

by picking up such stocked coke over the next period before a reline while keeping the coke ovens at a constant level of production.

If real production control is to be established over pig-iron manufacture, adequate ore stocking, screening, and crushing facilities must be available, together with sintering facilities, in order to use all fine material. Only recently at Port Talbot have these been available, but, as in the case of the coke ovens, multiplicity of ores has rendered the task extremely difficult, and it is to be hoped that in the future it may be possible to operate foreign ore plants with large quantities of a few ores, rather than smaller quantities of many ores. Figure 4 shows the reduction of stocking capacity of any given area available for stocking ores with the increase in number of ores stocked. The Fairless works in the USA operates almost exclusively on Venezuelan ore, and has shown the excellent results that can be obtained when production is planned on the basis of a single ore burden, with all the accuracy of control that results.

Port Talbot is not laid out as anybody would lay out a blast-furnace plant today, starting with the knowledge of the desirability of crushing, screening, and sintering ore, the use of self-fluxing sinter, and the high percentage of fines now present in most foreign ores. As a result an extremely complicated raw-material layout has emerged and, in the very early stages, it became obvious that once again some form of control would be necessary. The so-called raw materials controller has in his office a mimic diagram, showing the operation of the plant at the various points at which ore is received, treated, and consumed. There are five transporter unloaders with two ship berths; two tipplers for home ore, limestone, and purchased coke; an unscreened ore stock, a screened ore stock, and a fine ore stock; primary and secondary crushing and screening plant; and three sinter plants. When to this complexity is added the fact that there are in general use 24 different ores, and two different kinds of limestone, it will be clear that the operator has a good deal to think of, including a hundred different belts, covering a total distance of 13 miles.

This is excessively complicated, and endeavours are being made to eliminate certain belts, cut down the numbers of ores, and produce self-fluxing sinter requiring no further addition of limestone. The control is in operation 24 h daily, and actions must be rapid to ensure that the plant is kept operating. The controller may be confronted by the fact that two ships have arrived alongside, both containing ore which requires screening, or by the fact that when screening an ore making much fines, the space available for the fines of that particular ore in the fine ore stockyard is nearly full. He must be capable of reaching a quick decision under such circumstances.

The largest existing control is that of the scheduling and production department. The object of this department is to schedule and progress customers' orders through all processes, from the steel-plant ingot production to the finished rolling-mill products, in accordance with the order delivery date, the quality, and the quantity. This schedule is governed not only by customers' requirements, but also by the necessity of scheduling in accordance with efficient rolling-mill practice.

Customers' orders pass from the sales department to the order control department, who issue the orders to the mill in accordance with the sales department plan. The first step in the mill's scheduling department is to mark the order with the metallurgical routing programme required. The order is then passed to the department carrying out the calculations necessary to convert the customer's order into hot-rolled coil weights and dimensions. The order form, with this information upon it, then passes to the hot-mill scheduling department, which computes the coil sizes into slab and ingot dimensions to achieve the best possible yield. The steelmaking plant receives from this department orders for steel grade and ingot size and type to achieve the hot-mill schedule.

The information regarding steel casts as they are made passes back through the ingot controller to the soaking pit planner, who schedules the ingots, and then through the soaking pits and slabbing mill and up to the shearing stage. The slab shear operator then passes back to the hot-mill scheduler the lists of slabs actually sheared, and with this information the hot-mill scheduler builds up his records of slabs in stock

from which he makes up his actual hot-mill rolling schedule. On all hot strip mills this must invariably begin with narrow strip, widening out rapidly to a given maximum and slowly returning to a minimum width in order to compensate for heating-up of the roll and roll wear.

A certain amount of mechanization has already been introduced. In the first case, the sales department, by combining the order with punched tape carrying common information, produces punched tape from which punched cards can be produced. This punched tape also produces an order card which is the common form used in connexion with the customer's order throughout its life. The punched cards are then fed through a machine to produce every week a list of all orders so sorted that they appear in order of descending width and gauge, and in separate qualities. This is the basic information from which the hot mill scheduler prepares the mill schedule.

To deal with failures to roll, the punched card goes to the mill together with the order. In the event of it being rolled the card is destroyed; otherwise the card is returned to the office to take part in the next week's run-through.

It is not possible in this short address to explain the complexities of this whole system. It is enough to say that later I will deal with the proposals to mechanize this whole system completely.

At a level of production of about two and a half million tons, it became clear that it was necessary to install a more formal production-control department for the works as a whole. This is now going into operation. The object of this department is to assist general management in achieving improved control in detail over the immediate production situation by using up-to-date information regarding the situation throughout the works, and a more accurate insight into future production trends by using past experience, as well as to plan for the future in predicting the works situation for a considerable time ahead.

The production controller is responsible to the assistant general manager in charge of operations. The first step of the production controller is to ensure that he is in possession of accurate and up-to-date information about what is going on in every department. This involves the supply of regular returns from each department, and also immediate information when any change takes place, such as unexpected breakdown, failure of a ship to dock, or anything that might disturb the pattern on which forecasts and planning have previously been made. With such information, the production controller is able to make an accurate forecast of the output of each section of the plant, and of the requirements of raw materials.

He makes an accurate forecast of the expected production of each department for a week ahead each Friday; a 12-week forecast is also published every Friday, the previous week being taken off and one week added, and a long-term forecast 5 years ahead is also made, the first year being in quarters and the remainder in half years. When preparing these reports, the controller has to consider short-term variations such as rebuilding of OH furnaces, normal planned maintenance for the various mills, and minor breakdowns or overhauls throughout the plant, and he also has to consider, in ample time, the variations that will be brought about by holidays, whether they be for one part of the works and not another, such as the Christmas stop, or one part of the company and not another, such as the tinplate division stopping when the steel division keeps operating, or holidays of suppliers and consumers, such as the NCB and the press works.

Ever since the start of operations at the Port Talbot strip mill the works has operated under conditions of full output. The production-controller's functions will have further complications at any time when demand falls below capacity, but, as yet, no experience in this field exists.

Long-term repairs such as blast-furnace relines and coke-oven rebuilds are also important; at regular intervals, moreover, it becomes necessary to replace certain assemblies such as the slab shears, motor armatures, or perhaps a blast-furnace bell and hopper. Past experience can be drawn upon to show the effect of a Christmas stoppage or a blast-furnace reline, but occasionally the production controller may be confronted by the effect of, for example, a large colliery strike or even a strike of one portion of the works, necessitating an immediate recasting of all his plans.

It is clear that no production-control department can give satisfaction unless it works in the very closest co-operation with the order section of the sales department, the repair planning departments of the engineers, and the purchase department, which deals with the supply of raw materials.

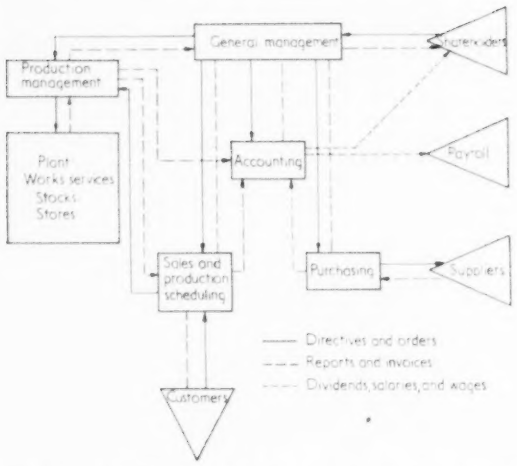
The production controller occupies a room on the walls of which are diagrams showing the main raw materials and semi-finished stocks, forecast and actual productions, and forecast and actual repair plans. The great danger of such a department is that when striving to improve the control, undue complications may set in.

The immediate effects of the establishment of such a department are that the sales department has a more accurate forecast of the probable production of the works and, therefore, closer agreement between their promises and deliveries, and the raw material purchases can be made on a more intelligent basis, due to considerable foreknowledge of events, enabling them to purchase pig iron perhaps well in advance in preparation for a blast-furnace reline.

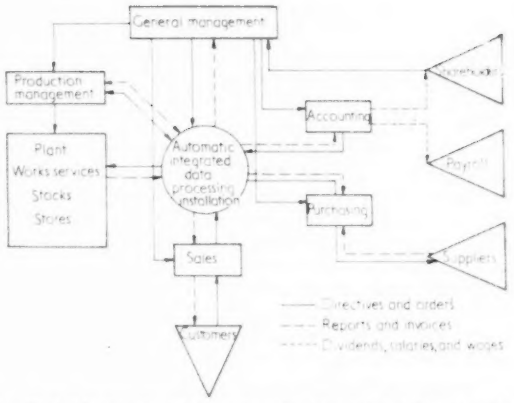
One of the most important features is the efficient deployment of bricklaying labour to achieve a balance between high slab-furnace availability and high OH-furnace availability. This one section of production control involves the planning of the employment of 320 bricklayers. Setting on one side the regular employment of men such as those repairing ladles, there is frequently a very difficult decision to make as to whether it is better to allow the strip mill to operate on a reduced number of slab furnaces, to concentrate on repairs to OH furnaces, or whether in only a short time there may be an embarrassment of slabs and a shortage of strip rolling capacity.

One of the most important functions of the production control department is to see that realistic yield and consumption figures are used in forecasting, and not those which the departmental manager would like to think were his usual achievement.

The state of production control we have now reached is well known to be merely a first move in the direction of more mechanized control of the whole operations of an integrated iron- and steelworks. For instance, it is already well known how to run all the operations of a



5 *A simple illustration of loosely connected separate departments comprising control side of a steel company*



6 *Probable way in which automatic integrated data processing will ultimately work in every large integrated iron- and steelworks*

slabbing mill from punched cards suitably prepared. Very recently the Great Lakes Company has ordered an automatic control system for its new 80-in. hot strip mill which it is stated will control all the operations from the time the slabs enter the mill until they emerge in rolled coils, using 200 key points along the route to feed information back to a computer which will so control the mill that the correct gauge and width are consistently produced.

At the Homestead works of the U.S. Steel Corporation the whole scheduling and production control from receipt of customer's order to shipping the finished plate is being carried on one large computer installation, an IBM type 650 tape Ramac system, having a magnetic drum of 20 000 digits, four Ramac units of 24 000 000 digits, and six type 729 magnetic tape units of 150 000 records, each having 30 characters.

Ideally, the system of the future will be such that the sales department will have a list of every product the company can produce and a display from which they can deduce the delivery they should quote for any order. They should also have continuously available the expected date of delivery and position in the plant of any order already taken. To achieve this ideal result, information must flow to a central communication centre from every piece of plant which may affect the production programme. In some people's minds is the thought that this information should flow automatically, so that, for instance, the output of a flying shear cut-up line would be recorded at the central communication centre from the machine without human intervention. Others feel that the capital cost of such an elaborate communication system will never be justified. However, the control of major units in the mill direct from punched cards is now clearly possible, and if this is so, the outputs of all major units can be unquestionably received at the communication centre immediately, so that it appears to be a question to be decided on the merits of each piece of plant whether to cable the recording mechanism direct to the communication centre or to continue to transmit information from time to time from records.

Figure 5 is a simple illustration of the loosely connected separate departments which now comprise the control side of a steel company. It is no longer a question of whether computers and automatic data processing will be introduced into iron- and steelworks, but simply a question of how soon and in what way will they be employed.

Figure 6 shows the probable way in which automatic integrated data processing will ultimately work in every large integrated iron- and steelworks. This shows quite clearly that in the course of time the main functions of general management will be to improve the technique of control, to take personnel decisions, and to be more and more concerned with long-term problems such as selection and training of staff and less and less with day-to-day problems, as the automatic data processing unit increasingly becomes capable of taking decisions on what should be done in the event, say, of a breakdown or a change in the order position.

The extrusion of steel

E. K. L. Haffner and J. Séjournet

SYNOPSIS

The extrusion of steel has made great strides in recent years. The progress made applies not only to the actual technique of working, but also to the design of the presses and other items of equipment that make up the modern plant.

The following paper endeavours to set out the progress made and current trends; the ranges of possibilities are indicated and some of the problems encountered are discussed. The principles of extrusion are well known and are therefore not dealt with in any detail. 1784

PRODUCTION TECHNIQUE

Preparation of steel billets

THE EXTRUSION PROCESS for the production of solid sections and tubes consists essentially in the placing of a billet, which has previously been heated to the appropriate temperature, into an extrusion press container. By the subsequent exertion of pressure the metal is deformed permanently, when this passes through an extrusion die, during which process it is rapidly transformed into a long product of the required section. The details of this process are well known and therefore will not be elaborated upon further.

The material is generally supplied in the form of long, rolled or forged round stock, which must be free from any surface and internal defects.

In the case of alloys that are difficult to extrude (other than ordinary steels), the surface of the bar must be carefully scalped or turned. When cast billets are being extruded, their surface must be turned or ground, and local defects carefully ground out.

The incoming stock is cut into billets by means of circular saws or abrasive discs.

When tubes are being extruded, a hole for the extrusion press mandrel must be provided through the billet, before extrusion. This may be carried out either by cold machining, which is done for holes of small diameter, or by hot piercing when larger diameter holes are involved.

Billet heating

In the lubricated extrusion process the outside surface of the billet becomes the surface skin of the extruded bar. To avoid the formation of defects on the surface of the extruded product, it is necessary that clean billets, at the correct extrusion temperature and free from surface oxidation, are fed into the container. Various means have been used to achieve the non-oxidizing heating of billets:

(i) The *salt bath furnace* was originally used and it had the advantages of achieving a quick and uniform heating without any oxidation. The billets were coated with a film that protected them from oxidation during the handling operation upon discharge from the furnace. Furthermore, there was an easy loosening of the superficial oxide scale, which may have covered the surface of, say, ordinary carbon steel, before heating. Unfortunately this method of heating was very costly, a serious disadvantage when heating the cheaper-grade steels

(ii) *Gas furnace with special atmospheres.* In such a furnace the gas is not fully burnt in the furnace proper, the combustion being finally achieved outside the furnace and the available heat being recuperated; this allows for oxide-free heating. One such furnace is in operation for the heating of ordinary mild-steel billets

(iii) *Low-frequency induction heating.* A considerable number, approaching some 80 units, of this type of heater are now in operation or under construction, and although costs of such units are high, they are being increasingly used for billet heating before extrusion. (A later section of the paper deals more fully with the development of this type of furnace)

(iv) For some special alloys, *resistance or muffle furnaces* have been used and in these the billets are protected against oxidation by a vitreous coating

(v) The *Balestra glass-bath furnace.*

Extrusion presses

The presses used in conjunction with the glass-lubricated extrusion process have certain special characteristics, and have been the subject of numerous developments and improvements, when compared with presses used for non-ferrous extrusion. In particular the tooling is designed to ensure a correct flow of metal, discard sawing and ejection, and quick

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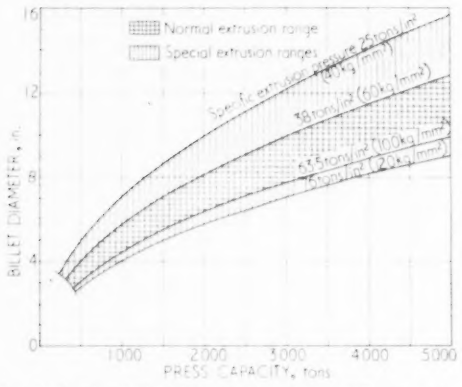


1 *Graph showing billet diameter ranges, for different extrusion press sizes*

mounting and changing of dies and die holders. All these are aspects that have received much study and a later section of the paper deals with press developments in greater detail.

Finishing equipment

After extrusion and cooling, the solid sections are mostly straightened and de-twisted in a stretcher. During the stretching operation the coating of oxide covering the bar is loosened and often only a quick pickling or shot-blasting operation is required to complete the cleaning. The tubes are generally pickled chemically and are then straightened in a roller-straightening machine.

Range of production

The production range of an extrusion press is essentially a function of its capacity, which itself is based in some measure on the following factors:

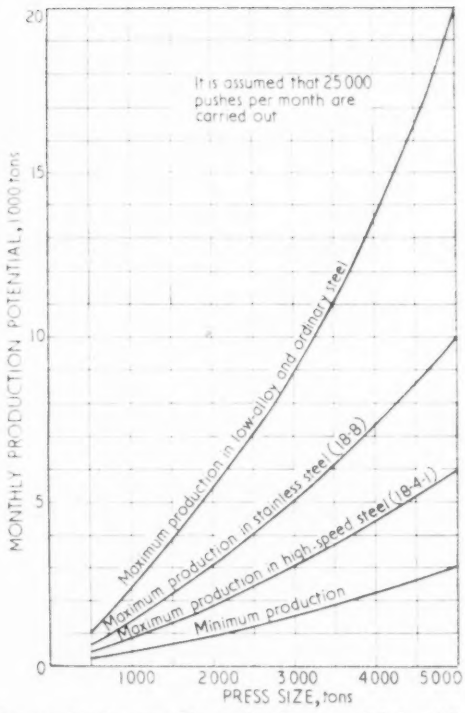
(*a*) the minimum and maximum size of product to be extruded
(*b*) the minimum and maximum tonnage which it is desired to produce
(*c*) the nature of the metal or alloys being extruded.

It is quite obvious that, generally speaking, the greater the press capacity the larger the principal dimensions of the extruded products and the higher the hourly output in weight.

In Fig.1 are shown the ranges of billet diameters that normally find application in extrusion presses; it is possible to produce in an extrusion press any section that can be inscribed within a circle which, in extreme cases, need only be 2 in. smaller in diameter than the bore of the container being used. The range of diameters of containers is a function of the press capacity.

The weight produced from an extrusion press is dependent on the number of extrusions per hour that can be achieved for any particular alloy.

Figure 2 shows the output potential for different press sizes and for different alloys on the assumption of a sustained production of 25000 extrusions per month.* There is for each press capacity a considerable margin between the potential minimum and maximum



2 *Curves showing monthly production potential for different steel extrusion press sizes*

output, which is the result of the difference in weight per foot of product that can be extruded from a given press; naturally the heavier the product per unit of length, the greater the output.

It is of interest to give a few details of the products that are at present most frequently extruded. These are:

(i) shapes that cannot be rolled, e.g. finned tubes
(ii) products that could be rolled, but where the required quantity is not sufficient to warrant the manufacture of rolls, which are considerably more costly than dies. It is thus possible to produce economically some non-standard sizes
(iii) products that could be rolled, and for which there are rolls available, but where the quantity involved in any order would not warrant the cost of a mill roll change. It is possible to carry out small contracts quickly in an extrusion press.

By way of an example, it is interesting to examine the production ranges of, say, a 2000-ton press:

Thin tubes

Stainless-steel tubes of 0·1–0·118 in. (2·5–3 mm) wall thickness can be extruded, having outside diameters between 1 and 5·125 in. (25 and 130 mm) and in lengths varying from 20 to 60 ft (6–18 m).

Medium-thickness tubes

Alloy-steel tubes (e.g. for boilers) having a wall thickness ranging from 0·2 to 0·315 in. (5–8 mm) can be extruded with diameters ranging from 1·2 to 5·125 in. (30–130 mm) and in lengths varying from 16 to 50 ft (5–15 m).

* *Note:* 25000 pushes represent 500 operating hours at a rate of 50 pushes per hour.

Thick tubes
Tubes of bearing steel, having wall thickness from 0·315 to 0·6 in. (8–15 mm) can be extruded with inside diameters ranging from 0·75 to 4 in. (20–100 mm) and in lengths varying from 16 to 50 ft (5–15 m).

Very thick tubes
Tubes from 0·6 to 0·8 in. (15–20 mm) wall thickness (e.g. for mechanical applications) can be extruded with inside diameters from 0·75 to 4 in. (20–100 mm) and in lengths varying from 13 to 40 ft (4–12 m).

The smallest diameters quoted in the above four cases would only be applicable for very small quantity production. If larger quantities were required, larger tubes would be produced and then subsequently brought to size by appropriate reducing means.

Finned tubes
Ordinary steel tubes having 8 fins, inscribed within a circle of 4·3 in. dia (110 mm) having an inside diameter of 1·18 in. (30 mm) and weighing 4 lb per ft run, can be extruded in lengths of approximately 50 ft.

Other hollow sections
A great variety of hollow sections can be extruded: e.g. hexagons with an inside diameter of 2·35 in. (60 mm) weighing 1·2 lb per ft run.

Solid sections
The range of solid sections that can be obtained in ordinary steel and stainless steel extends from approximately 1 to 34 lb per ft run. However, the larger sections must be inscribed within a circle of about 6 in. (150 mm) diameter.

GLASS LUBRICATION

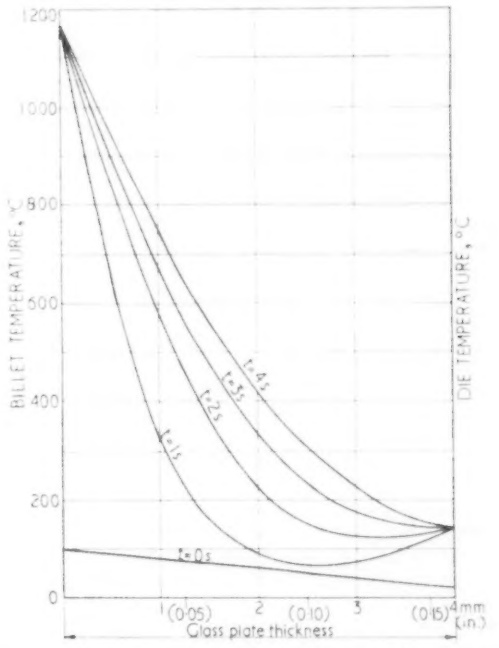
If a billet is placed inside the container, it is clear that lubrication must be ensured on the following surfaces:

(i) the front face of the billet, i.e. the surface in contact with that of the die; this is the most important location for lubrication
(ii) the outside surface of the billet, which is in contact with the container wall
(iii) in the case of tube and hollow extrusions, the inside surface of the billet, which is in contact with the mandrel.

Lubrication of the front face of the billet

It is interesting to examine what happens to a thick glass plate placed between a cold die and a hot steel billet. Figure 3 shows the abscissa indicating the thickness of the glass plate and the ordinate the temperature. At the beginning, the face of the glass against the die has a temperature very close to that of the tool, while the face in contact with the hot billet is rapidly heated to a temperature close to that of the billet. The instant when $t=0$, the temperature gradient across the thickness of the plate between hot billet and die is approximately represented by a straight line. In practice there occurs an immediate heat transfer, and after 1 s for example ($t=1$), the curve of temperature equilibrium, which can be calculated, takes the form indicated in the figure; at this instant the billet is pressed against the glass plate with a very high specific pressure (25–75 tons in^{-2}).

The viscous layer of glass having been brought to a temperature that allows it to flow under pressure, is drawn along by the metal movement and flows with it



3 *Curves showing variation of temperature with time of contact, across glass plate thickness*

through the die, coating the extruded bar with a film of glass.

In Fig.3 it is assumed that all the glass heated to a temperature that exceeds 1070°C will flow and it can be shown that this represents a layer of glass about 0·004 in. (0·1 mm) thick.

As such layers of viscous and fluidified glass are caused to flow through the die under pressure, new layers of glass come into contact with the hot billet and in their turn become viscous and flow in the same manner. Finally, the extruded bar is coated with a film of glass, the thickness of which is about 20 μ (0·001 in.).

The mechanism of the glass lubrication method consists of a progressive and continuous melting of the glass which is drawn along by the metal being extruded. The lubricant used must melt over a range, i.e. it must have a viscous phase. If a lubricant that liquifies instantly were used, then upon fusion, the lubricant would be ejected in an irregular manner, and there would not be continuous lubrication, which is avoided when glass is used. A continuity of lubrication is an indispensable characteristic for satisfactory results.

To study the characteristics of various glass analyses, the research laboratory of Compagnie de Saint-Gobain developed a new technique using tools made radioactive. It thus became possible to determine with surprising accuracy the thickness of the glass film at any point on the extruded bar, as well as the corresponding wear of the tools.* The thickness of the glass coating depends on a number of factors. Since the formation of the glass cover is governed by a law which is a function of time and of the thickness of the glass plate itself, one can understand the great importance of extrusion speed. Die profile and, in general,

* B. Jaoul: Booklet No.14, Société Française des Mécaniciens.

tool design play an important part in obtaining an even flow of the glass film and of the metal itself.

In practice extrusion is carried out at high speeds (about 20 ft/s); so that the extrusion operation itself does not take longer than several seconds, and a considerable deformation is possible in an extremely short interval of time.

The main properties of the glasses, which have been found to be of primary importance in order to enable them to play an effective role as high pressure lubricants for extrusion, are heat diffusibility and viscosity.

Diffusibility is represented by the ratio of $\lambda/(\mu \times C)$, i.e. the thermal conductivity divided by the product of specific heat and specific weight. It represents the ability of any glass under consideration to diffuse the heat transmitted by the hot metal. It became apparent that most glasses have almost identical diffusibility properties, so that it was not necessary to investigate the variations in this property. On the other hand, the viscosity of glasses varies considerably, depending upon their chemical composition. For the extrusion process the viscosity at the working temperature must have a value that lies within rather narrow limits. It is, therefore, necessary to select glasses that are suited to any particular extrusion temperature. There is now a range of vitreous products of widely different viscosities available to give satisfactory results for all known industrial applications.

Originally cast glasses were employed in the form of plates for die lubrication and in tube form for mandrel lubrication. One of the principal difficulties encountered at that time was that the plates and tubes fractured when suddenly brought into contact with the hot billet, the pieces of broken glass causing defects on the extruded product. Many tests were then carried out using glass in other physical forms, such as multicellular glasses, glass fibres, glass wool, glass cloth, etc. The industrial lubricants now actually being used consist essentially of mixtures of glass powders, which are readily obtainable commercially at a reasonable price.

Lubrication of the outer surface of the billet

This problem is the easiest one to solve, since in this case the glass plays an identical part to that of conventional lubricants. It is sufficient to surround the billet with glass lubricant before loading it into the container. If the necessary precautions are taken, the vitreous material spreads itself as evenly over the billet as oil would do over a metallic surface. The lubrication of the exterior of the billet makes it possible to extrude very much longer products than would be the case if no lubrication were used. The pressure at the start of extrusion is, furthermore, considerably reduced.

Lubrication of the billet bore

The principles are the same as those that apply to the lubrication of the outside surface. Originally glass tubes were used, with the difficulties already indicated above; these tubes were replaced by a glass veil, until nowadays glass powder is introduced into the billet bore just before extrusion.

ECONOMIC ASPECTS OF THE EXTRUSION PROCESS

Impact of the extrusion process on manufacturing economics

Extrusion can today be considered as a commercial process for the production of sections and tubes in all qualities of steel, from the most ordinary to the most complex. *The first experimental plant utilizing glass was started up in Paris in 1942: the plant installed at Persan was the first one utilizing glass on a commercial basis, as early as 1950.* The question of costs of this new production process has been raised on numerous occasions. The larger firms have endeavoured to determine whether this process is already capable of replacing the more conventional rolling process. Today there is little doubt that for some production ranges such as the manufacture of stainless-steel tubes, ordinary carbon-steel finned tubes, all profiles of lesser or greater degree of complexity in ordinary carbon steel, in fact for the hot-working of most steels, the use of extrusion as a working process represents a commercially economical method, the development of which has been coming more and more to the fore in recent years. The firm that developed the glass lubrication application, and has worked with the latter to a large extent in one of its own plants, is well qualified to carry out a general review and comment on future trends. Furthermore, there is available also the experience accumulated by the licensees of the process, which enables predictions of future developments to be made on the basis of actual data available.

It is of interest to recall that the development of the glass lubrication process was the result of efforts that actually started in 1942, but were limited at that time to pure research, only getting fully under way from 1950 with the starting-up of an industrial plant. Although there has been much sustained progress, and many aspects of the technique of glass-lubricated extrusion have been mastered inasmuch as they give reproducible results and permit the planning of production programmes, it is nevertheless equally true to say that the effects of a number of factors remain as yet unknown. The field of research, in order to make the process more perfect, is today greater than at the start. If one considers all the efforts that have gone into the rolling of sections or tubes and which have been made by technologists all over the world, backed up by vast production programmes, over a period of very many years to reach the results known today, then by the time a similar effort will have been applied to the extrusion of steel it is probable that in its sphere of application it will have made much headway, not improbably at the expense of some of the rolling applications.

It can be said that since 1950 the extrusion cost price, irrespective of the products concerned, has diminished regularly every year, and that those firms which have applied to this process the same efforts that they may have reserved for similar processes in the past, will have drawn from their efforts more lucrative returns than they have derived from other spheres with the same amount of expenditure. Hence, it would sometimes appear to be a more economical proposition to spend time and money on the development of a new process, part of which has already become commercially profitable, than on spending time and effort on the development of an old process.

Extrusion cost price

In order to elaborate more clearly on the problem of extrusion cost price, it is necessary to define just what exactly is meant by this, and when discussing equal

cost prices to know whether there are some factors that will influence a decision in favour of or against the extrusion process. It is clear that the cost price consists of many items which are well known and which depend often on local conditions, the price of labour, the price of raw material, the supply of electricity, the cost of heating, etc. It is easy in any particular case to determine the cost price for an extrusion operation at a particular works. This cost price is, however, related to the hourly output that can be obtained from an extrusion press. The greatest progress that has been made in the last few years has been the ability to design special-purpose steel extrusion presses, which are capable of hourly outputs very much greater than were originally visualized as being possible.

Today steel extrusion presses are laid out for a potential production in excess of 100 extrusions per hour and the billets that can be extruded in the container are longer than previously possible. The billet length was limited by increasing friction and therefore by the required load that had to be applied; as the glass lubrication process greatly reduces friction, there would in this respect not be any great practical limit to an increasing billet length. However, it must be stated that with the present state of knowledge, when products are extruded in lengths greater than, say, 55–60 ft, tooling difficulties become apparent.

The present series of new presses currently under construction are capable of handling billets 50–100% longer than those with which it has been the custom to extrude up to now, and it is hoped, bearing in mind also that it is the intention to achieve double the number of extrusions per hour that was previously carried out on the older presses, to obtain approaching four times the hourly output that was considered satisfactory say, nine years ago, for a given press size.

Some examples and indications of extrusion production capacity have previously been given, and it is interesting to note that one of the presses that will shortly be installed will be served with heating capacity suitable for dealing with up to 20 tons/h, and ultimately for the larger sizes, up to 40 tons/h will have to be heated. Therefore, one begins to contemplate hourly outputs approaching those of tube mills.

Essentially, cost price per unit of weight of product depends on the number of tons per hour that are produced, on power cost to drive the presses, heating costs, handling and manpower costs, maintenance and overhead charges, costs of tooling, etc. Furthermore, depreciation as well as interest charges on invested capital all enter into the price. Such factors, which play a considerable part, vary between one country and another and can often, depending on government policies, make the difference between making extrusion economical or not in marginal production ranges, thus depending on country and the particular time under consideration.

Very often the final investment involved is greater than that originally planned, but inasmuch as the output is proportionally greater, this is often justified, for the minimum cost price of extruded products is achieved in a plant which is designed for the maximum output rate.

Extrusion versus rolling

Concerning the comparative cost price between extrusion and rolling, which is a point often raised, the following aspects should be mentioned:

(i) the starting material is generally of better quality in the case of extrusion than for other processes, and so its price is slightly higher. On the other hand, as the extrusion process starts with higher-quality material, it also yields a high-quality product and, furthermore, the metal losses in the process are smaller than for orthodox processes. One can say that this advantage compensates for the disadvantage of a higher price, and the production cost by extrusion, taking into account the output, is very close to that of rolling

(ii) for an equal output, the investment required in the case of an extrusion plant is less than that for rolling

(iii) as an extrusion press is capable of carrying out in one single operation a much more substantial deformation than a rolling mill, it follows that the proportionate space required for the process is much smaller, and thus the overall area is less for the former

(iv) at first sight the tool wear is approximately similar for extrusion and for rolling; there is therefore no great difference in this respect. For similar hourly outputs the labour required for an extrusion plant (and this is dependent upon the degree of mechanization possible) can be of the same order as that required for a rolling mill

(v) the energy costs required for extrusion are lower than those for rolling; on the other hand, to offset this, there is the necessity of having substantially oxide-free heating, which means slightly greater heating costs

(vi) the cost of the vitreous lubricants as used in the extrusion process is practically negligible, the only expense to be reckoned with being that of the glass removal. However, this is not considerable, and for normal applications shot-blasting generally suffices to give acceptable surfaces.

From the above it would appear that there should be no reasons why the cost prices of extrusion should vary considerably from those of rolling, if extrusion is considered in the same way as rolling, i.e. on an industrial scale and no longer on an experimental basis.

Clearly, in the estimation of the total cost price and in an analysis of such factors as will have to be considered when coming to a decision as to whether extrusion or rolling should be used, certain other aspects of a purely technical nature may come into play. Thus, for instance, one canont always ignore existing plant; attempts may have to be made to improve this and try to achieve higher outputs from it. In some cases, one may not be able to consider the complete elimination of an existing plant, in order to replace it at once by an extrusion plant.

Such existing plants are found in the more highly industrialized countries; it is, therefore, in those countries or firms which do not have existing older and more conventional production means where one will see the extrusion of everyday products developed first. However, in some instances the installation of an extrusion plant can already be justified in competition with a rolling mill; for example, when products of a superior and consistent quality are required, such

as alloy-steel tubes. In fact in the field of tube manufacture, one wonders whether the ability of being able to produce a thin tube in one single extrusion operation will not bring about the situation where this process must, by its very availability, one day replace that which consists of producing thick blanks which have to be drawn down afterwards in order to obtain the thinner product.

The willingness to accept new techniques is more slow in those industries where large investments are involved. In the rolling-mill field, large organizations have available a substantial staff, used to the process, while in the extrusion field the number of trained technicians in the world is as yet relatively small, and their training in this new process is of necessity long and difficult.

Summarizing, it can be said that the extrusion of steel is at present developing rapidly. As time proceeds the cost price is being lowered, and the ranges of application are extended. Steel extrusion can no longer be ignored, and whenever the installation of a new section or tube plant is contemplated, it has now to be seriously considered.

LAYOUT OF MODERN PLANT

The following deals with plant layout, trends in press design rquirements, hydraulic circuit considerations, and instrumentation. The notes are kept on general lines, indicating current developments and thoughts rather than being directed towards the specialist.

General requirements

When considering the layout of a modern steel extrusion press plant, all auxiliary machinery and equipment must be so arranged in its physical location and output potential as to be closely geared to the production of the extrusion press.

Increased output from modern extrusion plants is achieved by:

(1) the utilization of very much faster and more effectively designed hydraulic presses
(2) the maximum possible utilization of semi-automatic or automatic handling, reducing manpower requirements to a minimum
(3) the utilization of low-frequency induction heaters, with their attendant advantages, for billet heating
(4) the careful planning of layouts for new plants.

Main plant components

Considerable developments have taken place in ideas on steel extrusion plant layout during the last two to three years, the overriding objective being, of course, to ensure the easiest flow of material, which implies the careful co-ordination of the various units constituting the plant. Key units which have to be thus co-ordinated are:

(i) the billet preparation section
(ii) the low-frequency induction billet heating installation
(iii) billet conveying systems and glass lubrication devices
(iv) the piercing or expanding press (for tube manufacture)
(v) the extrusion press
(vi) the runout and quenching devices, or alternatively the runout device, cooling-bed conveyor, and stretcher system, as applicable
(vii) pickling baths, shot-blasting cubicles, drawing section, etc., as applicable.

The design of any layout must be extremely flexible, so as to permit a ready change of routing of the billets, to conform with the different production sequences and methods by which it must be possible to work with a modern plant. Furthermore, instant re-routing should be possible, should a breakdown occur in part of the plant, or the requirement of immediate maintenance or tool changing make this necessary.

Typical layout

Figure 4 shows in principle a typical layout of a modern steel extrusion plant, utilizing low-frequency induction billet heaters. The layout shown must be regarded as typical only, as conditions vary widely. As shown, the rolled or forged steel bar is cut to the required length for the billet and placed into a cold billet stock area. Under alternative arrangements (e.g. when hollow billets of small diameters are used), these may have to be pre-drilled and in some cases machined before arrival at this area. From here the billets are conveyed to one of the induction heaters shown, and thence, after passing through the necessary lubricating devices, are (*a*) transferred directly into the extrusion press, or, when on tube production, (*b*) taken into the piercing press; in this case they may be, after piercing,

(i) transferred to one of the induction billet reheaters and thence into the extrusion press, or
(ii) taken directly into the extrusion press, or
(iii) taken to the cold pierced-billet stock area.

If the billets are transferred from the piercing press to the cold pierced-billet stock area, this implies that they may be machined before reheating prior to extrusion, in order to give a special surface finish, or for other technical reasons.

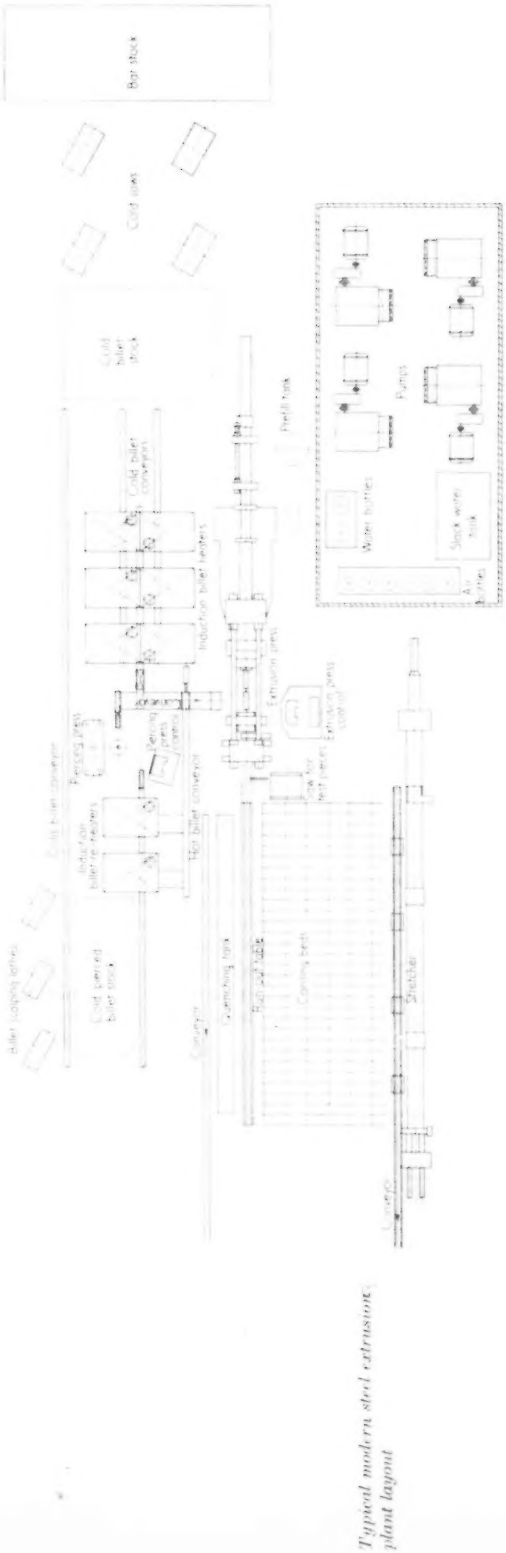
Under alternative conditions, pre-drilled billets may be led directly to the extrusion press, while the piercing press can be used for other production purposes.

Piercing press

Since hollow billets are generally supplied to the steel extrusion press for the production of tubes, the piercing press has become an essential and integral part of the modern steel extrusion plant. This was brought about by the exacting requirements of tube concentricity and the need for the lubricant to be on the mandrel during extrusion; this is particularly the case for thin-walled tubes.

Before extrusion, the billets may be drilled, pierced, or expanded from a small pilot hole, drilled previously; the size of tube to be produced and economic considerations decide which type of preparation is to be used.

Billet expanding is claimed to have advantages over piercing, and at present appears to be the more favoured method of producing hollow billets with very good concentricity. The number of press and handling operations is reduced from that required for piercing, and the power and pressure water consumption is also smaller.



4 *Typical modern steel extrusion plant layout*

It is clear that the piercing press should be as close to the extrusion press as possible.

Billet handling equipment

The application of the requisite lubricant both externally and internally (where applicable) to the billet requires much auxiliary equipment, some of which is extremely complex, as it is the aim to carry out most of this type of operation without the use of manpower. In fact, the necessity and the desire to keep the manpower required to a minimum, with resultant semi-automatic and automatic handling of billets and operation of the presses, has had a considerable influence on the arrangement of layout and accounts for the increasing complexity of equipment.

The handling equipment for the billets, to and from the induction billet heaters, and the various routing arrangements between piercing press, reheaters, and extrusion press, presents major problems, for it is essential that billets are conveyed at the highest possible speed after heating is completed, to avoid scale formation and heat losses. The time delay before the application of glass lubricant after billet heating is critical and must be kept to a minimum.

All handling gear and all moving mechanical parts throughout the plant must be so designed as not to be adversely affected by the presence of some glass powder in installations where this lubricant is used.

Hydraulic pressure station

On the layout shown the hydraulic pressure station complete with its pumps, control equipment, etc., is housed in a separate building. This has a number of advantages from the aspects of maintenance and tidiness, as well as ensuring that this equipment is well isolated from any possible intrusion of glass powder.

Other auxiliary equipment

After emerging from the extrusion press, the product is led into a runout trough and thence either tilted into a quenching tank or alternatively on to the cooling bed, whence it is automatically conveyed to the torsion stretcher. The torsion stretcher is of a specialized design, having to cope with extruded products in a distorted condition. This stretcher must be capable of de-twisting extruded products along either part or the whole of their length.

When planning a new steel extrusion plant, the functional requirements that dictate the relative positioning of the various units of the plant must have overriding priority. The claims of any existing building layouts must be considered as secondary to the need for an efficient and economical functioning of the plant.

It is furthermore important to have adequate material overflow and storage areas throughout the plant, to allow for variations in the production programmes and alternative routing.

PRESS DESIGN REQUIREMENTS

During the last 10 to 15 years, in some measure also as a result of the adoption of the Ugine-Séjournet process of glass lubrication, the extrusion of steel has become commercially practicable. Table I shows a typical range of steels and other metals and alloys now being extruded on a commercial scale, and Fig.5 indicates the extrusion ratio and specific pressure ranges that

TABLE I Commercially extruded materials (glass lubrication), arranged in order of increasing resistance to deformation

Material	Extrusion temperature °C	Extrusion temperature °F	Typical chemical composition, % C	Mn	Mg	Si	Cr	Ni	Mo	W	V	Ti	Fe	Co	Al	Cu	Resistance to deformation (aver.) lb/in.²	kg/mm²
Steels																		
Carbon	1200±100	2190±180	0·1–1·0	0·3–1·5	...	⩽0·1	...	...	...	...	...	...	Remainder	...	...	...	18500	13
Low-alloy	1200±70	2190±125	0·2–0·6	0·3–1	...	...	0–1·7	0–3·7	0–0·3	...	...	...	,,	...	...	...	21300	15
Stainless	1175±25	2150±45	⩽0·15	1	...	⩽0·5	11–13	...	...	...	...	...	,,	...	...	...	25604	18
Stainless	1175±25	2150±45	⩽0·15	⩽1	...	...	11·5–13·5	...	...	...	...	...	,,	...	...	...	25600	18
Stainless	1180±30	2160±55	0·03–0·10	⩽2	...	...	18–20	8–12	...	...	...	⩽0·4	,,	...	...	...	27000	19
Stainless	1180±30	2160±55	⩽0·08	⩽2	...	...	17–19	9–12	...	...	...	...	,,	...	...	...	28400	20
Stainless	1170±20	2140±35	⩽0·25	⩽2	...	⩽1·5	24–26	19–22	2–3	...	...	...	,,	...	...	...	32700	23
Stainless	1160±20	2120±35	⩽0·03–0·08	⩽2	...	...	16–18	10–14	...	...	0·9	...	,,	...	...	...	34100	24
High-speed tool	1140±20	2080±35	2	0·3	0·3	...	12	...	...	18	1	...	,,	...	...	...	35500	25
High-speed tool	1110±20	2030±35	0·7	...	...	...	4	1·1–1·8	...	...	...	...	,,	...	...	0·0·7	42600	30
Nodular cast iron	1050±25	1920±45	3·1–3·5	0·3–0·5	0·04–0·09	2·4–3·0	...	...	...	...	...	...	,,	...	...	...	31250	22
Nickel and nickel alloys																		
Nickel	1100–1200	2010–2190	...	...	...	...	...	99	...	...	...	...	...	...	...	...	25600	18
Inconel	1150±25	2100±45	⩽0·15	⩽1	...	⩽0·5	14–17	Remainder	...	...	...	...	6–10	...	...	...	39800	28
Nimonic 80A	1150±20	2100±35	⩽0·1	1	...	⩽1	18–21	,,	...	...	...	1·8–2·7	⩽5	...	0·5–1·8	⩽2	42600	30
Nimonic 90	1150±20	2100±35	⩽0·1	⩽1	...	⩽1·5	18–21	,,	...	...	...	1·8–3·0	⩽5	15–21	0·8–2·0	...	45500	32
20–20–20 type	1150±15	2100±25	⩽0·15	1·5	...	⩽1	21–22	19–20	3	2·5	...	...	Remainder	20	...	...	45500	32
S.816	1160±10	2120±20	0·4	1·5	...	0·7	20	20	4	4	...	...	3	43	...	Cb=4	49800	35
Other metals																		
Titanium	850–900	1560–1650	...	...	...	...	...	...	...	...	...	...	...	...	...	...	17100	12
Molybdenum	1300–1400	2370–2550	...	...	...	...	...	...	...	...	...	...	...	...	...	...	56900	40

are involved. Figure 6 shows a selection of typical hollow and solid sections in carbon, stainless, and high-speed steels and Nimonic alloys, produced by extrusion. This has resulted in considerable changes in the design of extrusion presses, the major changes having taken place in the last one or two years. For a long time several older extrusion presses were adapted for steel extrusion, but such adaptations (e.g. of presses designed for the extrusion of brass or copper) did not really prove satisfactory, and were not suited to the many exacting demands now made of a steel extrusion press, and such units are now largely being replaced and augmented by more modern presses.

The modern steel extrusion press handles billets in the diameter ranges shown in Fig.1, and it has to operate at very high main ram speeds. Figure 7 shows the range of main ram and outgoing speeds with which presses and their auxiliary equipment now have to work.

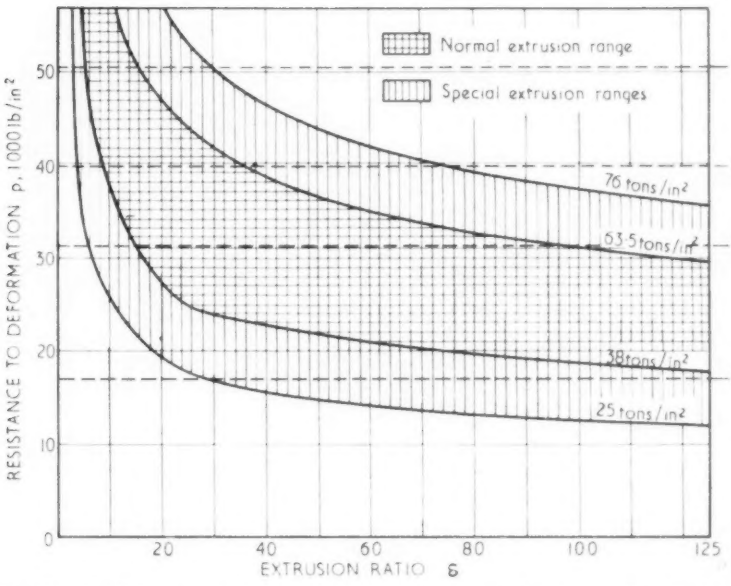
The basic requirements of a steel extrusion press are that it should be structurally capable of operating under the high speeds of working now required, and that it should be reliable in operation and of such rigidity and alignment accuracy as to produce tubes to the very close wall thickness tolerances that are necessary.

Multi-cylinder presses

For reasons that will be enlarged upon in a later section, all high speed steel extrusion presses operating to date are working in conjunction with air–hydraulic accumulators. Following the practice of utilizing multi-cylinder arrangements in free forging presses which give various power stages, the same expedient is being used in steel extrusion presses of recent design; e.g. in the case of the series of 3000-ton steel extrusion presses currently being built, instead of having a single cylinder of 3000 tons capacity. Where the only means of varying the press tonnage would be to reduce the working pressure of the accumulator, it is possible, by means of a multi-cylinder design, to have six equal power steps ranging from 500 tons up to the full load of 3000 tons. This makes it possible for the press to be used for an extremely wide range of production, say, from 5 to up 14 in. dia. billets with lengths varying from 6 to 40 in. This necessitates using varying lengths of container, which in turn poses a number of problems to the press designer, as the position of contact of the container and die face remains constant, whereas the front face of the container has a variable position. Thus it follows that the billet loading means must move with the container front face; it is furthermore essential, in order to save time and pressure water, to make the stroke as short as possible, and this in turn introduces design problems having regard to such aspects as pressure disc loading.

As yet the combined piercing and extruding of steel billets in one operation in the steel extrusion press is not carried out, because of the problem of maintaining lubrication for the extrusion of the billet immediately after piercing as previously mentioned.

Hollow billets are used, so that the mandrel power required may be comparatively small and could be provided by a mandrel-moving cylinder located within the main ram. With the multiple power stage design of press, however, a separate external cylinder which can act as a mandrel mover or independent piercer is



Note The resistance to deformation p is that used in the extrusion formula

$$F = \pi R^2 \times p \times (\log_e \delta) \times e^{2fl/R} \quad \text{(for solids)}$$

or

$$F = \pi (R^2 - r^2) \times p \times (\log_e \delta) \times e^{2fl/(R-r)} \quad \text{(for tubes)}$$

where F = extrusion force required, R = radius of container, r = internal radius of tube, f = friction coefficient, and l = length of billet extruded

5 *Chart showing resistance to deformation for different extrusion ratios and materials*

used so that the power of this unit may be added to any combination of main cylinders.

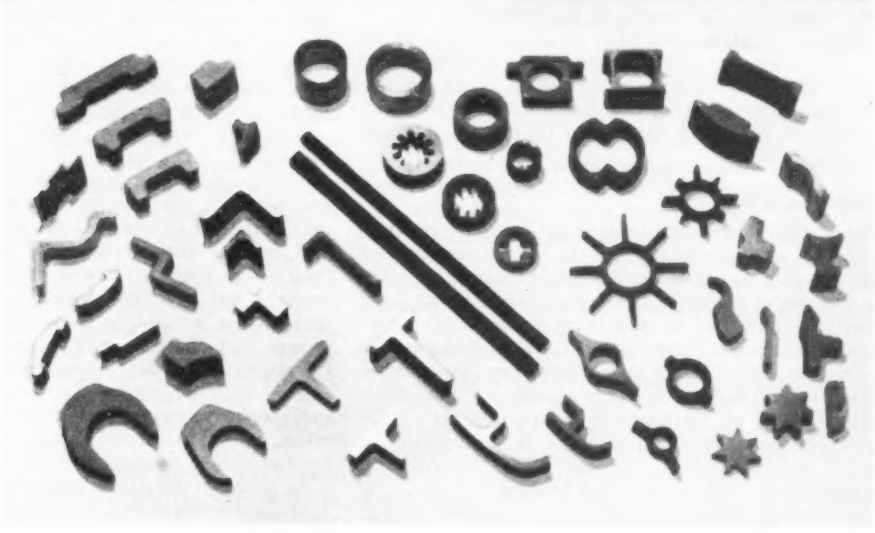
Method of press mounting

As extremely high extrusion and also auxiliary press movement speeds are required in modern presses, in order to meet the demands of maximum output, special consideration has to be given to the mounting of the press upon its foundation. On the more slowly operating presses, the press main cylinders are secured to the bedplate, and that in turn to the foundations. If this type of arrangement were retained in a fast-acting modern steel press, the foundations would have to withstand the shock loads. To overcome this, special arrangements are made to ensure a flexible mounting of the press on the bedplate.

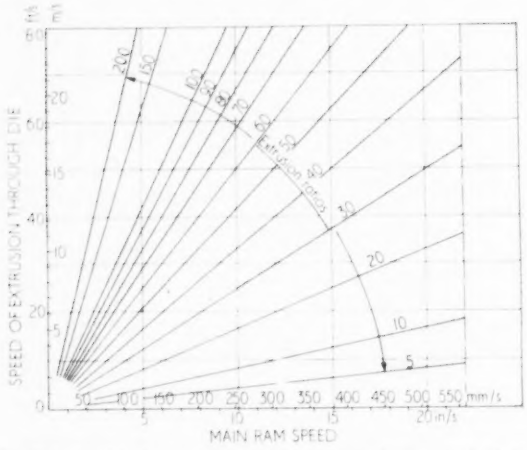
The absence of a rigid fixing of the press implies that high-pressure supply lines, and in fact all hydraulic mains between control valves and press, must be capable of 'taking-up' any press movement.

Automatic method of operation

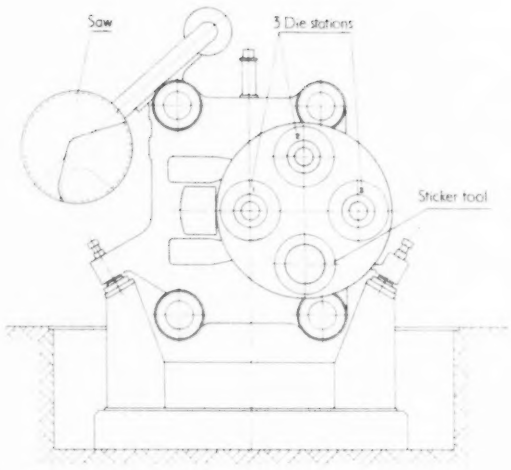
To obtain high production rates, it is necessary that automatic, or at least semi-automatic, working of a large number of press movements is possible. A fast automatic cycle can only be achieved by the overlapping of a number of operations. Care has always to be taken that the relevant press parts are in the correct location before safely initiating the following movement. For example, if the extruded product is being cut in front of the die, it is essential to ensure that the discard has remained in the container, when the container has moved away from the die by a short appropriate amount. If this cannot be automatically



6 *A selection of typical hollow and solid sections produced by extrusion using glass as a lubricant*



7 *Relationship between the speed of the main ram and of the extrusion through die*



8 *Rotating die carrier arrangement*

proved before the sawing operation starts, the cycle must be arrested while the operator satisfies himself that the sawing movement can in fact be initiated. If the extruded section is cut immediately behind the die, this particular danger does not exist in the extrusion cycle, and automatic operation can be continued after this particular juncture.

Similar situations are in existence throughout the cycles and the above example is merely given to indicate the problems that have to be solved in the design of semi- or fully automatic sequences, and when establishing the necessary system of interlocks.

Billet and disc handling gear

The billet and disc handling gear, mainly as a result of the high speeds of the press movement required, presents a number of mechanical design problems. If it is desired ultimately to carry out production cycles up to the region of 100 per hour, it is not possible to allow for 'dwell' times, or speed 'slow-downs', in order to afford a safe clearance for the billet loading gear; this gear must clear the path of the main moving crosshead when this is advancing at high speed.

The disc handling gear must accept the disc with the discard after 'stripping' from the container, and deliver these to the discard separator. After the discard has been removed, the disc must automatically go through a cooling system to be fed back to the extrusion press.

Rotating die carrier

It is of the utmost importance to keep the press in operation and extruding for the largest portion of time possible, and it is for this reason that the revolving die carrier system was adopted (Fig.8), making it possible to have two or even three die assemblies continuously in consecutive operation. Thus it is possible to clean and, if necessary, to exchange one die assembly while a second one is actually in operation on the press centre-line. It is, furthermore, a requirement of the latest presses that die assemblies be automatically loaded and unloaded into and from the rotating carrier and securely locked after loading.

In order to obtain the maximum sustained output from a steel extrusion press, it would, of course, be ideal to use a fixed billet diameter of a constant maximum length. However, this condition is unobtainable in practice, certainly under European conditions, so that the continuity in production is often broken by the requirements of tool changing. Therefore much development and thought has had to be devoted to finding means for reducing the tool changing times to a minimum, the requirement being that a complete tool change, involving the container and stem, should be possible within about 30 min. As previously mentioned, the multiple die station with its automatic die loading and unloading has resolved the particular problem of stoppages during production, while dies are either inspected, cooled, cleaned, or changed.

Extrusion mandrels

Similarly, the need for mandrel changing constitutes another break in the continuity of production, so that mandrel changing times are also now kept to a minimum. In order to facilitate a quick and easy mandrel change, a number of different methods of attaching the mandrel to its holder are being utilized. The older method of screwing the mandrel into the holder is still used, but the screwing time is kept to a minimum by means of a motorized gear.

Although very much higher production rates are demanded of the modern press, this has not implied any lessening in the demand for tubes of the optimum concentricity, and one of many factors contributing to good tube tolerances is the achievement of a correct and 'square' alignment of the container sealing face relative to the die. Means have to be employed to ensure that the container moves and aligns itself correctly in relation to the die face. It is essential to ensure that the container moves parallel throughout its stroke; this can be achieved by using a single central cylinder, or by the careful design of a twin-cylinder arrangement. In another patented arrangement, special alignment cylinders are used to 'square-up' the container relative to the die.

In order to achieve a maximum mandrel life, it is necessary to prevent its overheating during extrusion,

while it is in contact with the hot billet; it is therefore necessary to arrange for effective mandrel cooling to take place either during the extrusion stroke, continuously, and/or during the 'idle time' of the total extrusion cycle. Owing to the higher extrusion speeds now employed and the more effective insulating properties of the glass lubricant between mandrel and billet bore, the mandrel life, expressed in number of extrusions per tool, has gone up considerably. Since tool costs constitute a considerable portion of the total conversion cost from billet to tube, this is an important saving; furthermore, the need for less frequent mandrel changes again implies a reduction in the stoppages in the continuity of production.

The extrusion mandrel, apart from having to be cooled, is also liable to a certain 'thinning-down' due to the increased gripping effect towards the end of extrusion, when there is once more a slight increase in the specific pressure required, and where the combined effects of temperature and specific pressure tend to weaken the mandrel. In order to reduce this effect, mandrel-release gears have been designed which allow the mandrel to be dragged forward during this last portion of the extrusion stroke at a slightly faster rate than the speed of the main ram.

Many of the auxiliary adjustments on the press that were formerly done manually, now have to be capable of remote actuation on the part of the press operator, working at his control station. For example, owing to the fact that varying billet lengths imply the need for a variation in mandrel lengths, it is necessary to be able to alter the relative position of the mandrel in relation to the stem. Similarly, the mandrel must also be capable of being readily adjustable in its axial position in relation to the die face, and this also must be capable of being achieved by the press operator without leaving his control desk.

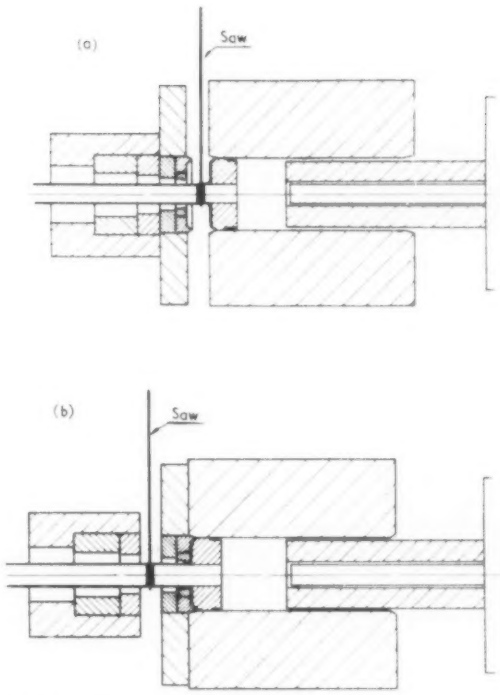
Discard sawing

It is important that the maximum length of extruded product is obtained from a given billet, and so the discard thickness must be kept to a minimum and the extruded product must be severed as close as possible to the discard. This is achieved by withdrawing the container away from the die, the discard remaining intact within the container bore, thus pulling the extruded section back slightly through the die; the saw then cuts between die and container (*see* Fig.9*a*). It is not uncommon for the discard to stick to the die face instead of remaining inside the container bore; when this occurs, a clearance is formed behind the die assembly, and the saw is traversed back to this point and then cuts the extrusion behind the die, as shown in Fig.9*b*. The discard and stub are then rotated with the die assembly to the station outside the press and removed. Cutting the product behind the die has the disadvantage that a longer stub length is left with the discard and that this has to be separately removed.

Special patented devices allow for the mandrel to be employed for parting the tube from the discard by a shearing action, eliminating the use of a saw under certain circumstances.

Container cleaning and heating

One of the main practical requirements that has been found necessary as a result of operating experience is the need for the cleaning of the container-die sealing face and bore after every extrusion; it is also advantageous to remove any glass dust and powder from the container bores.



9 *Alternative sawing positions*

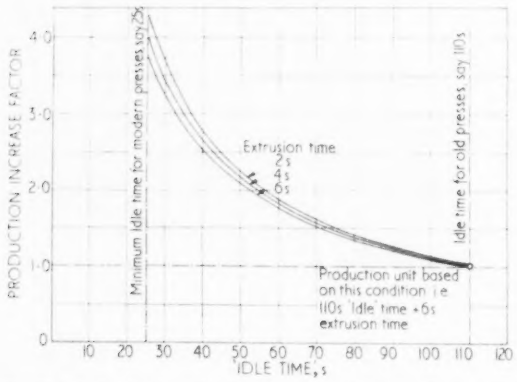
One recent form of container cleaning unit consists of a rotating wire brush system moving in from the front face of the container, proceeding through the bore right up to the die and back again. This necessitates the full withdrawal of the main ram to allow for such a brushing gear to move on to the press centreline, and thereafter to make a complete forward and return stroke along the whole length of the container. The length of this stroke is irrespective of billet length and constitutes a loss of time when very short billets only are being extruded.

A much improved device has been recently developed, which is very rapid in operation, where the press only makes a short stroke.

The heating of containers is not a critical problem, as in the case when extruding non-ferrous alloys. For steel extrusion, the container requires heating up, before the start of extrusion, if the plant has not been operating for some time; this is easily achieved by a gas heating system on the periphery of the container or by an electrical heating system. Once extrusion has begun, heating is no longer necessary, and, in fact, with sustained production container cooling is applied.

Stroke limitation

Discard thicknesses are frequently varied, depending on the billet size, product, and alloy being extruded. Owing to the extremely high pressing speeds often involved, it is necessary to use a positive overall stop-plate arrangement, to ensure that the moving cross-head stops 'dead' at the correct discard thickness, which is often extremely small when extruding steel.



10 *Effect of reduction of 'idle time' on the increase of production*

On the older type of press, a stop plate was normally mounted on the container face in the shape of a horseshoe, and if on this type of plate allowances were to be made for varying discard thicknesses, it was necessary to change the distance or spacer rings on the front face of the moving crosshead, requiring considerable time. As this type of discard thickness adjustment might have to be made as frequently as once every half an hour or more often, it was necessary to locate a stop-plate arrangement elsewhere than on the container, and to ensure that thickness variations could be carried out with a minimum of delay.

Runout tables

With the very high exit speeds through the dies when extruding steel, special consideration had to be given to the design of runout tables. In practice a trough-type section has proved to be the most advantageous, as it gives good support to the extruded product during its fast outward movement.

Many secondary design points have to be carefully watched. For example, it is necessary to guide the extruded section from a point as close as possible to the back face of the die, and also to cover the trough locally at the platen end to guard against the extruded product rising above the guiding trough. The trough also has to be fitted with cooling means in order to stand up to conditions of sustained production. The runout device, when moved out of the press, must be capable of being tilted, allowing the extruded product to roll out on to either a conveyor system or a cooling bed or quenching tank; where short heavy sections are being extruded, the speed of the tilting movement must be capable of being controlled.

Provision of tool cooling

Much importance is now attached to having a minimum of 'idle time', i.e. that proportion of the total press cycle when the press is not actually engaged on piercing or extruding operations, and the next section of this paper deals with this aspect in greater detail. Figure 10 shows the very considerable increase in production that is obtainable by a reduction of idle time. However, all efforts to cut down this non-productive part of the cycle to a minimum, and all the expensive and complex mechanisms that are used to achieve this end, will be to no avail if the press is held up by overheated tooling, whether container liners, mandrels, or dies. It is for this reason that much thought has had to be given to the problem of the provision of effective cooling of press tooling. Quite apart from the obvious disadvantage of having to hold up production while such tools are cooled or changed, the overall tool life figures become uneconomical, unless effective cooling is provided.

Protection from glass powder

When glass lubrication is used for steel extrusion, certain precautions have to be taken, e.g. if the deposition of fine glass powder is allowed on sliding parts of the press, this could result in wear taking place in an extremely short period of time. Thus all press slides that cannot be effectively covered or protected must be fitted with special materials which are either immune to the effect of glass powder or allow its removal to be easily carried out. Where such methods cannot be adopted (e.g. on rams and certain other moving parts of the press) these are protected by bellows or fixed covers and carefully sealed against the intrusion of glass powder. Forced lubrication can also be used in some parts, as a means of preventing the glass powder deposition.

Instrumentation of an appropriate type is now regarded by press builder and plant operator alike as an essential part of a modern steel extrusion plant, making it possible to see how efficiently the process is carried out, and a later section of this paper deals with this aspect in greater detail.

HYDRAULIC CIRCUIT CONSIDERATIONS

The hydraulic extrusion press, and where applicable its associated piercing press, constitutes the key unit in a steel extrusion plant. It therefore follows that since the extrusion press is the master unit governing output, it should be utilized to give the highest yield and efficiency. This implies, as previously indicated, a minimum of idle time, resulting in the maximum number of extrusions possible; furthermore, the press must be correctly 'loaded', provided that the order book permits this, i.e. it should always work at the highest power stage possible for any given conditions, the ideal utilization being achieved when by appropriate selection of extrusion ratio, billet diameter, and length and a consideration of the other well known factors, it can be operated as its maximum tonnage.

The modern steel extrusion press has to operate at very high main ram speeds, sometimes in the region of 12–16 in./s, and some idle movement speeds on the latest presses also reach values of up to 25 in./s or more, in order to meet the stringent requirements of short idle times. It might be argued that with a minimum idle time of say 25 s, the need for a reduction of extrusion time proper from, for instance, 6 to 3 s is not worthwhile, not least bearing in mind the additional cost of providing the valves and piping system necessary to achieve such extrusion speeds. The answer to this lies in the tool life factor; it is well known that when steel is hot worked, whether by die forging or extrusion, the shorter the contact time between hot metal and tooling, the longer the tool life; i.e. the less frequent the need for inspection, re-dressing, and replacement of the dies, the better the plant utilization and the lower the cost of the product. Besides this, productivity also increases with a reduction of extrusion time, as shown in Fig.10.

Hydraulic circuit efficiency

The ability to provide high speeds of extrusion has, however, to be coupled with the availability of an appreciable proportion of the press tonnage. Thus 80–90% of the rated press force has to be available at the same time as the required speed. It is therefore proposed that for new steel extrusion press specifications the hydraulic circuit efficiency is laid down, where this is defined as:

$$\frac{\text{Effective pressure available on main ram of press at rated speed}}{\text{Pressure available at accumulator or pumps}}$$

It is undeniable that in the past such efficiencies had values of 40–60% and sometimes even less. This was almost always the result of incorrect hydraulic circuit design, it was to a lesser extent also due to attention not having been paid to a correct loading of the press. Careful hydraulic circuit design involves that attention be paid to such aspects as pipe and valve friction, fluid compressibility, and water hammer, the latter so as to avoid shocks in the system.

It was at one time accepted as 'inevitable' that one-third or even more of the pressure generated should be lost in 'speed'. Inasmuch as this was deliberate, it may have been the desire at one stage to ensure that the press exerts its power under the condition of maximum power transmission efficiency, i.e. the product of press tonnage and rated press ram speed should be a maximum.

This occurs when the hydraulic losses in the circuit are one third of the pressure head generated.

Let v = nominal pipe velocity at rated press speed V_r

H_a = pressure head of water generated and available at accumulator station

H_e = effective pressure head available at press cylinders

H_f = pressure head of water lost in friction in pipes, valves, etc. between accumulator station and extrusion press cylinders

k_1 = a constant

k_2 = a constant

It can be stated that approximately

$$H_f = k_1 v^2$$

$$H_e = H_a - k_1 v^2$$

Power available at press cylinders $= V_r H_e = k_2 v (H_a - k_1 v^2)$

Differentiating w.r. to v and equating to 0 for a maximum

$$\frac{d(\text{Power})}{dv} = 0 = H_a - 3k_1 v^2.$$

$$\therefore k_1 v^2 = \frac{H_a}{3}$$

i.e. when the hydraulic circuit losses are one-third of the available accumulator head, the press is operating under conditions of maximum hydraulic power transmission.

However, this does not represent an optimum utilization of the extrusion press, which as previously mentioned should exert 80–90% of its tonnage at the rated speed. Whereas the power cost of 'pushing' say a 25 in. long billet of 9 in. dia. through the die of a 3000-ton extrusion press may be only 10*d*, the cost of the conversion of the whole billet to the final extruded tube may be in the order of 600–700*d*. It is thus important not to obtain a disproportionate impression of efficiency of working; it is necessary to distinguish carefully between the concepts of hydraulic efficiency, as distinct from that of overall plant efficiency.

Trend towards automatic operation of presses

The early extrusion presses were hand-lever operated by an operator in the usual manner. With the increasing number of valve blocks, dictated by the additional devices being hydraulically actuated (main ram, piercer, container, locking plates, shears, saw, discard separator, die runout, die change, etc.), the operator had to attend to an increasing number of levers, often most awkwardly arranged around him, apart from lubricating devices and billet conveying systems. This not only involved him in considerable physical fatigue, but also limited the speed at which the press could be operated over long periods.

The next step was the actuation of the various movements by small servo levers, which caused the valve controls to be operated by the application of oil pressure. This more remote actuation enabled valve blocks to be placed below floor level in spacious and accessible cellars, so that the whole cluster of equipment around the press driver was removed from sight. This then meant that the press operator could operate the press from a neat control desk conveniently located in front of him, giving a clear field of vision. The servo control system gave finger-light control and enabled the operator to concentrate on the extrusion process while no longer exposing him to physical fatigue and making it possible for him to co-ordinate his function with the other members of the press crew to a better extent and more in keeping with the higher rates of work demanded.

Servo hand-lever actuation was soon followed by semi-automatic and then fully automatic operation for certain extrusion cycles. Where semi- or fully automatic operation is provided for, it is nevertheless always arranged that the operator can at will when necessary (e.g. for adjustment purposes or when a 'sticker' has occurred) go back to servo hand-lever operation or actuate push buttons or other hand-operated switches.

Considerable discussion has arisen on the desirability of automatic working; experience has indicated that when a press is engaged on a simple extrusion cycle for a substantial part of its operating time, each cycle being identical with the next (e.g. on simple rod of profile extrusion), there is no cause for the operator to depress a number of push buttons, in the same sequence, 60 times or more an hour, throughout the shift; under such circumstances automatic actuation is not only warranted but almost essential to reduce human error, which can easily occur with the complexity and operational speeds of modern extrusion presses.

For more complicated extrusion cycles it is occasionally advisable to interrupt the automatic sequence during certain critical stages in the cycle; this method of working is described as semi-automatic.

Choice of fluid, working pressure, and type of drive

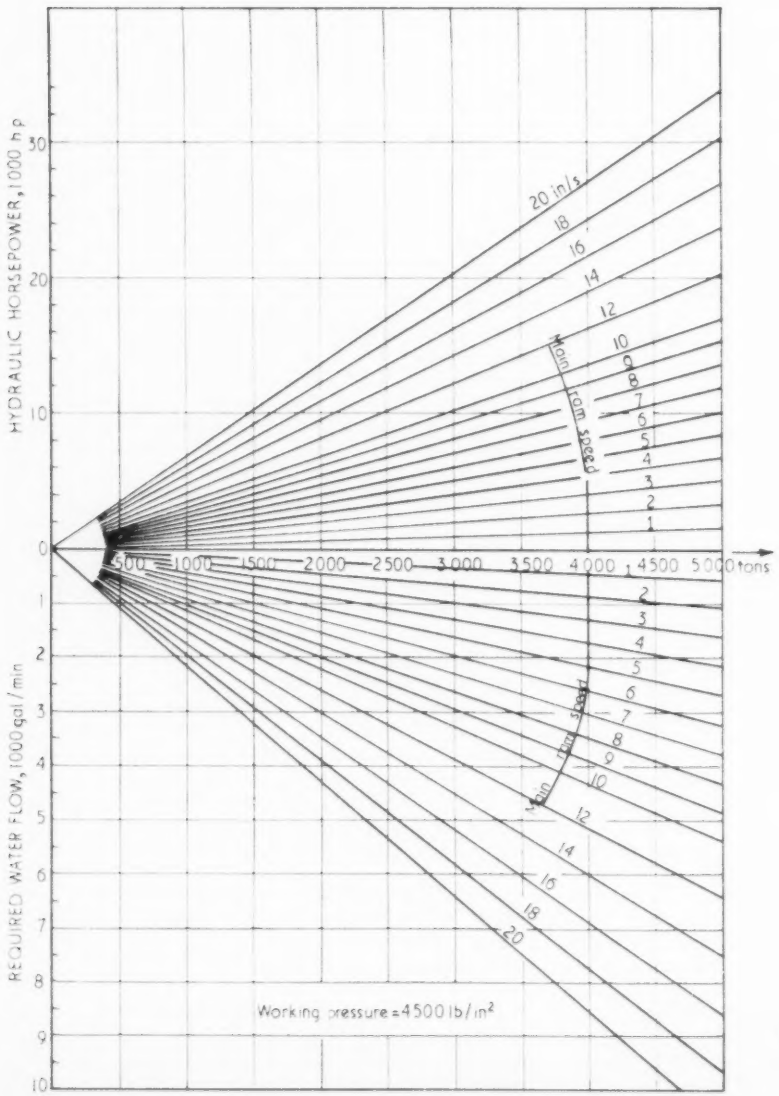
For the extrusion of hot steel, water has invariably been used in hydraulic press circuits. Very high penetration speeds being required for extremely short

periods of duration, air-hydraulic accumulators are employed. The water is used in a 'closed' system to which 1–1½% of soluble oil is added to avoid corrosion effects and to act as a lubricant. By having a 'closed' circuit the same water is used continuously and only small amounts have occasionally to be added to the system for 'making up'.

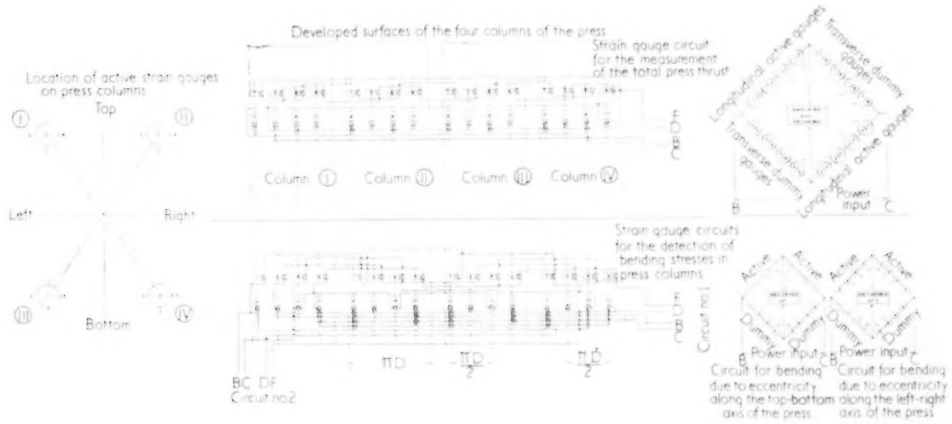
In the past, air–hydraulic accumulators have been employed with working pressures in the region of 2850–4300 lb/in² (200–300 atm), and as a rule 5000 lb/in² (350 atm) was not exceeded, as a marked amount of oxygen absorption into the water appeared to take place at higher pressures. Almost all accumulator plants installed in recent years work at a maximum pressure of about 4500 lb/in² (315 atm), having a mean nominal rating of 4300 lb/in² (300 atm), which is considered to be a reasonable compromise of the various factors involved.

The use of too low a working pressure necessitates increased ram, valve, and pipe sizes, and at the high working speeds involved in the extrusion of steel the momentum of the larger moving liquid volumes can be detrimental.

As mentioned before, for hot steel extrusion press applications, accumulator drive only has been considered, as the volumes required per unit of time (and it must be remembered that the total time of extrusion is only 2, 3, or at the most 4 s on modern presses) are extremely large. If direct drive were used, the volumetric capacity of the pumps would be out of all proportion, not to mention the very considerable temporary loads that would have to be carried by works mains. For many non-ferrous hot extrusion applications, however, direct drive is frequently used, for as far as power requirements during extrusion are concerned, economical operation is achieved, as the power output required from the pump motors is proportional at any instance only to the resistance being met.



11 *Hydraulic horsepower and water flow required for steel extrusion presses*


METHOD OF MEASUREMENT OF THE TOTAL THRUST AND BENDING STRESSES
Developed surfaces of the four columns of the press
Strain gauge circuit for the measurement of the total press thrust
Location of active strain gauges on press columns
Top
Left
Right
Bottom
Column I
Column II
Column III
Column IV
Longitudinal active gauges
Transverse dummy gauges
Power input
Strain gauge circuits for the detection of bending stresses in press columns
Active
Dummy
Circuit no1
Circuit no2
Circuit for bending due to eccentricity along the top-bottom axis of the press
Circuit for bending due to eccentricity along the left-right axis of the press

12 *Strain gauge circuit*

Apart from the previously stated reasons why accumulator drive is chosen for hot extrusion of steel, there is also the advantage of the possibility of feeding more than one press from one central station, which is also desirable when a piercing press works together with an extrusion press. Another advantage of the accumulator is a certain interchangeability of speed and pressure, although, as already mentioned, between 10% and 20% of accumulator pressure is allocated for the generation of speed, i.e. between 30 and 60 atm, for instance, are permitted in pressure losses through the piping and valve system (the same hydraulic pressure loss problem exists, of course, in direct drive circuits as well).

To achieve economical working the larger sizes of modern steel extrusion presses are provided with three, four, five, or even more power stages. It is necessary so to control the production programme that the press is 'loaded' as highly as possible.

Figure 11 shows the extremely large quantities of liquid required per unit of time as soon as high penetration speeds are required, at high press tonnages; the hydraulic horsepowers at these rates of fluid draw-off are also indicated.

INSTRUMENTATION FOR STEEL EXTRUSION PRESSES

It was decided that in the case of one of the new 3000-ton steel extrusion presses that is shortly due to be installed it would be desirable to incorporate appropriate instrumentation to give a better indication to the plant operator and press builder of press performance, and also to obtain more reliable data under production conditions.

Some of the main points of interest are:

(i) the variation in thrust exerted by the press during the extrusion stroke
(ii) the speed of extrusion
(iii) the temperature of the billet.

Until recently, most extrusion presses were, at best, fitted with a few ordinary Bourdon pressure gauges and a stroke indicator. It is, however, now recognized both by press builder and plant operator that a simultaneous recording, for instance, of pressure, speed, and/or stroke is of great value. It may be of interest to elaborate here on the measurements of principal interest.

Total press thrust measurement

It has recently become the practice to fit pressure transducers into the main cylinders of presses, and thus to assess the total load exerted by the press from the indication of hydraulic pressure. It is a simple and rapid method, but it has the disadvantage that such records of pressure are only indirectly indicative of the load exerted. When more than one cylinder pressure has to be measured (e.g. when a piercer ram adds its power to that of the main ram, or when a three-cylinder press is used with or without the addition of a piercer cylinder) the total load is the sum of that exerted by the individual cylinders. In such instances it would be necessary to install as many pressure transducers as there are cylinders and to employ a multi-channel recorder. An improved method of total thrust measurement is a system in which the distortion of an elastic medium on the press is taken as an indication of the load exerted. In such a method the elastic medium can either take the form of a specially inserted element or, for instance, the press columns themselves can be used. In this latter solution, shown in Fig.12, the total extrusion load is measured by means of electrical signals obtained from a set of strain gauges fixed to all three (or four, as the case might be) columns of the press. The gauges are wired in such a way as to eliminate the effects of bending and to record pure tensile loads only. The individual column loads are electrically summed up to give the value of the total load, irrespective of the combination of pressure cylinders used, for a given extrusion operation; only one recorder channel need be employed for the purpose.

Detection of eccentric loading by the measurement of bending stresses in the press columns

The possibility of eccentric loading in an extrusion press is very much more remote than, for example, on a forging press, in which the workpiece is often placed eccentric to either the longitudinal or the transverse

press axis, resulting in considerable corner bending moments existing in the columns.

In a new and well erected extrusion press there should be no eccentricity detectable at all; it may be that with time some very small eccentricities might occur in practice, as a result of an accidental slackening or uneven readjustment of the nuts on the press columns, the gradual wear of certain guide bushes, or a possible slight misalignment of the tooling assembly with respect to the press centre-line. Where this type of measurement might be desired by a press user as an additional facility, the columns can be wired with strain gauges in such a way as to eliminate the effects of direct load and only to show the strains due to bending. This type of circuit has been developed and patented for forging presses, where it is calibrated in terms of bending stress and gives a continuous visual indication on a cathode ray screen, suitably arranged to measure the eccentricity of loading at any time.

Provision can be made for a warning lamp, an audible alarm, or an automatic cutting off of the hydraulic power, in the event of the bending stress on any one of the columns exceeding a pre-determined danger value.

Alternatively, as shown in Fig.12, the signals from the strain gauge circuits can be fed to another channel or channels of the recorder for the purpose of obtaining a permanent record. Where no bending stress is present in a column, the relevant reading even under full press load is, of course, zero.

Stroke measurement

All modern extrusion presses are fitted with linear scales indicating the stroke of the main ram and piercer or mandrel mover; whereas this visual means is sufficient for ordinary production purposes, the necessity may arise of correlating the trace of the stroke with that of the total press thrust on a common record.

Extrusion speed measurement

The correlation of extrusion speed with the press thrust is generally of more interest than the correlation of the stroke with the load. Although the extrusion speed at any point of the stroke could be deduced from the stroke record, this method is an indirect one and does not lend itself for a rapid reading. It is therefore necessary, particularly in the absence of stroke records, to devise separate means for speed measurement.

Temperature measurement

The major location where temperature measurement is critical and has to be closely controlled is in the low-frequency billet induction heater. Billet temperature measurement in this type of heater is usually carried out by means of radiation pyrometers focussed on a point on the billet surface. These pyrometers are suitable for temperatures up to 1400°C, but normally the extrusion temperature range varies between 1050° and 1350°C, depending on the type of steel involved; the pyrometers are connected to temperature recorders.

The temperature measurement of the extrusion press containers is also undertaken, but presents no special problems, employing a straight-forward thermocouple arrangement.

Instruments

In order to secure permanent records of signals obtained from any of the above points of measurement, a further instrumentation unit is required, and this generally consists of an amplifier and a recorder.

The instruments available on the market vary from one another in their response characteristics, the method of chart tracing, and final accuracy. They are divided into:

(i) the industrial recorders of the potentiometric type
(ii) the laboratory instruments of the galvanometer or cathode-ray tube type.

The robust industrial recorders are fitted with long and wide charts, are stable, and do not require frequent re-calibration; they need little attention or maintenance and are well suited for applications such as extrusion plants. They have, however, a low-frequency response which, in the fastest recorders, is of the order of 4 c/s only.

Laboratory-type pen recorders are effective for frequencies up to 80 c/s, but they are more sensitive and require careful handling and adjustment.

In plants where the main emphasis is placed on routine production records rather than temporary research investigations, the natural choice is the industrial recorder.

INDUCTION HEATING OF BILLETS BEFORE EXTRUSION

General considerations

In recent years considerable developments have taken place in applying low-frequency induction heating to billets for steel extrusion. The induction heating technique varies from other forms of heating in that the heat is actually generated within the billet; also it does not depend on heat transfer to the billet from heated surroundings.

Induction heating equipment may be classified according to the frequency of the alternating currents fed to the induction coil in which heating takes place. Thus 'high' and 'medium' frequency equipment employs currents at frequencies greater than those used in commercial supply networks, while 'low' frequency equipment operates directly at the supply frequency. This latter type of equipment eliminates the converting machinery, which is expensive both to install and maintain, having regard to the power needed for extrusion requirements. For this reason it is not surprizing that the demand for clean and rapid precision heating of extrusion billets has been met by applying mains frequency induction techniques.

The comparatively high values of electrical resistivity common to all steels impose physical limits on the minimum diameters of billets in these materials that can be efficiently heated to extrusion temperatures using mains frequency equipment. However, this limitation has not proved to any degree restrictive since the demand has in practice corresponded with trends towards larger presses, involving the use of larger billet diameters. An indication of the variation of coil efficiency with billet diameter, when heating stainless steel at 50 c/s, is shown in Fig.13; this is based on typical billet lengths as used for extrusion, and allows for each diameter an appropriate air gap clearance between billet o.d. and coil i.d.

It will be seen that for large quantity production, a billet diameter of, say, 6 in. or above is desirable for the more economic utilization of the heaters. However, depending on the output required, it may still be found preferable to use mains frequency heaters down to 4 in. dia., since the other advantages obtained often more than offset the mere extra heating costs; heaters are, in fact, in use under such conditions.

Advantages of low-frequency induction heating

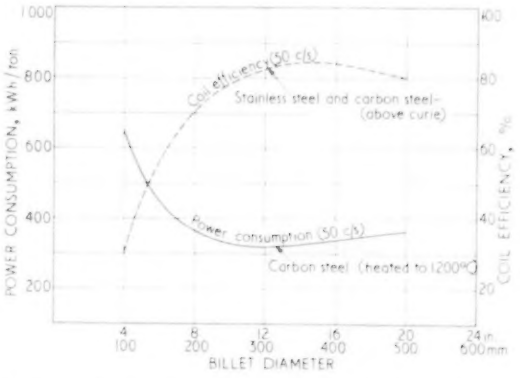
Some of the main factors that have contributed to the swing towards low-frequency induction heating in the last few years include:

(1) exact instrument control of the temperature of each billet, resulting in quality control. Each billet of a batch is brought to the same temperature (the temperature of each billet may be recorded). If the working programme calls for a change in billet temperature, this can be obtained immediately by adjusting a small setting knob. Optimum temperature conditions, once established, can be recorded and are reproducible at will for a similar production programme at any future time
(2) reduction in personnel needed to operate furnaces
(3) low-frequency induction heaters are readily adaptable for incorporation in schemes for mechanical handling of billets and for incorporation in semi- or fully automatic extrusion cycle operation
(4) the virtual elimination of maintenance compared to conventional furnaces (no major shutdowns for re-bricking, etc; a spare coil can be fitted in less time than it takes to fit the normal press tooling)
(5) reduced floor-space requirements in the working area, giving increased room for production
(6) no heating chamber of any size is required. The first hot billet is ready for extrusion within minutes of starting up, thus eliminating heating-up time and saving manpower. Moreover, the power consumed is proportional only to the billet output; no heating is required while production is interrupted for tool checking or changing, or for other reasons
(7) improved shop conditions, due to the absence of fumes and heat wastage to surroundings
(8) greatest possible flexibility in production programmes; alloy is changeable within a few seconds
(9) virtually scale-free heating.

The low-frequency heaters can, if necessary, also work with a reducing atmosphere in the heating coil, but it has often been found that, owing to the small air gap and the thermal conditions existing, together with the very short heating time, scale formation while heating is negligible.

Economic considerations

It is, of course, impossible to give heating costs that will apply exactly under all conditions when heating steel billets. Apart from the varying physical characteristics of different materials, it is often not appreciated that the rate of heating will have a notable effect



13 *Power consumption and coil efficiency curves for low-frequency steel induction heaters*

on fuel costs when heating to elevated temperatures. This arises from the fact that the lower the power input the greater the proportion of useful energy that will be wasted by radiation. Figure 13 also shows the typical power consumption that may be expected when heating carbon steel billets to 1200°C, assuming a normal rate of heating.

It must be emphasized that heating costs in themselves are but a single item in the overall production costs. Many of the listed advantages of induction heating have a most notable secondary effect in reducing overall costs. Thus accurate temperature control causes less scrap and wastage, while the elimination of scale formation means not only a direct material saving, but also results in a greatly extended life of extrusion dies and mandrels. It has also been found that certain intricate sections can only be extruded consistently and satisfactorily from inductively heated billets.

Further cost savings result from the fact that 'heating-up', 'stand-by', and 'hold-over' expenditure can be almost entirely neglected; this will obviously be of the greatest importance in a plant when single-shift working occurs.

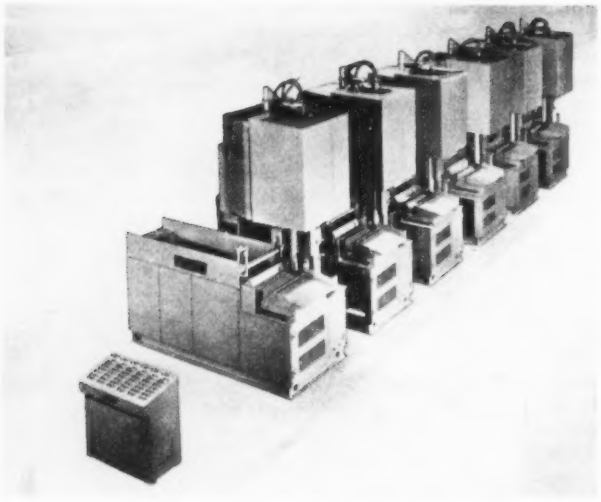
It is also interesting to note that where induction heaters have been installed to supersede conventional fuel-fired furnaces, an increase in production per man-hour has consistently followed. This is in part attributed to the mechanized billet handling systems generally associated with induction heating installations; however, the flexible performance combined with the fast rate of heating inherent with induction heating also contributes to this result.

Furthermore, for the preheating of awkward special materials which are sensitive to thermal shock and which have to be heated at a slower rate, long horizontal preheating coils are used. The use of induction preheating shortens the time required to reach the necessary temperature, as this method of heating does not have to rely on heat transfer to the billet from a hot chamber.

Design and construction features of mains frequency heaters

A general division can be made between alternative methods of construction:

(1) heaters with horizontally mounted coils, or
(2) heaters with vertically mounted coils.



14 *Battery of low-frequency steel induction heaters*

Usually the choice between these will be decided by the billet sizes involved. Each of the above main group may again be sub-divided into heaters having:

(i) coils to accommodate more than one billet at a time (long coils, e.g. preheating coils)
(ii) coils to accommodate only a single billet at a time (short coils).

The above may be combined, as required, to suit the particular technique to be employed, though for physical reasons the vertically mounted coil is best applied to the heating of single billets at a time. This form of construction has a very general application for steel extrusion requirements, since it reduces wear and damage to the high-temperature coil lining during billet handling, and is adaptable for adjustment to give desired temperature patterns, and for the use of controlled atmosphere heating, should this be needed. However, the long horizontal coil heater also has applications, particularly where billets are required at regular intervals (i.e. the programme will not be unduly broken up by intermittent and irregular interruptions). In steel extrusion plant this would apply more generally to the needs of piercing rather than final extrusion.

Other features of a well designed mains frequency induction heater should include:

(*a*) a main power switch to control the current to the heating coil
(*b*) means of adjusting the power input to the coil to suit particular requirements. (This is commonly achieved by feeding the coil through tapped transformers)
(*c*) a bank of power-factor correction capacitors, since the heating coils have a low inherent power factor
(*d*) means for loading and unloading billets in the coil. This may be achieved by either pneumatic or hydraulic means with electrical controls, ensuring that the operations are performed in the correct automatic sequence; alternative manual control may also be desirable for starting up and emergency conditions
(*e*) means for controlling the temperature of the billet. For this duty, thermocouples, radiation detectors, kilowatt-hour relays, and timers may be used in individual installations
(*f*) an efficiently designed water-cooling system, incorporating safety devices to prevent the overheating of the induction coils and other essential components.

In view of the heating times required for steel to establish an optimum heat pattern within the billets, it will often be found that multiple units are required to comply with the production requirements. The demands of the minimum of heating time and the corresponding power input required, will determine the rating of each unit.

Figure 14 shows a typical group of short vertical coil heaters intended for incorporation in one multiple unit installation.

The activity of ferrous oxide in silicate melts containing calcium and manganese oxides

I. M. Davidson, M.Eng., and C. Bodsworth, M.Met., Ph.D., A.I.M.

SYNOPSIS

The activity of ferrous oxide in $FeO–CaO–SiO_2$ *melts has been investigated in the presence of up to 12 mole-% manganese oxide by equilibration in pure iron crucibles with* $H_2–H_2O–A$ *mixtures in the temperature range 1265–1365°C. It is shown that the activity is lowered to values intermediate between those previously found for the* $FeO–CaO–SiO_2$ *ternary system and the corresponding values in the binary ferrous silicates. The decrease in the activity is not progressive with increasing manganese oxide concentration.*

Within the composition range investigated the activity is markedly temperature dependent. The activity coefficient increases with temperature at low ferrous oxide contents but the reverse effect is found at higher concentrations. The point of inflection moves to lower activity values with increasing manganese oxide content. The experimental data has been extrapolated to 1600°C to obtain the approximate location of the iso-activity contours and these are considered in relation to open-hearth steelmaking data.

An empirical formula is employed to compute the activity of ferrous oxide in these melts. A satisfactory fit is obtained when manganese oxide is treated as an inert diluent. 1770

INTRODUCTION

IN A PREVIOUS PAPER[1] one of the authors has reported the variation of the activity of ferrous oxide with composition in the ternary system $FeO–CaO–SiO_2$ and in the temperature range 1265–1365°C. For all compositions investigated the relationship between the logarithm of the ferrous oxide activity and its mole fraction was found to vary linearly with temperature and this relationship was used to obtain corresponding values of activity and composition at 1600°C so that the experimental results could be related to steelmaking conditions. The iso-activity curves presented at this temperature could also be compared with the earlier results of Chipman and co-workers[2,3] which have been replotted by Elliott,[4] and with the curves calculated from the available data by Turkdogan and Pearson[5] for melts covering the wide range of slag compositions encountered in steelmaking processes.

A reasonable agreement was reported between the three sets of data at low lime concentrations but as the lime content was increased beyond 20 mole-% the extrapolated iso-activity lines were located at higher ferrous oxide contents than were suggested by the previous investigators. This discrepancy is possibly accounted for by the fact that the earlier data are relative not to the ternary system but were obtained from more complex melts.

As reported in the previous paper[1] the composition range investigated was limited by the liquidus to compositions typical of the early, iron oxide-rich, steelmaking slags and to those encountered in the acid process. The principle constituents of such slags are ferrous oxide, silica, and lime with the remaining components present in relatively small quantities. However, in certain cases manganese oxide may become one of the major constituents of the slag, particularly in refining slags which lie in the above composition range. Hence a logical extension of the present programme has been an examination of the effect on the activity of ferrous oxide of manganese oxide additions to the $FeO–CaO–SiO_2$ ternary melts.

Complex melts containing manganese oxide have been investigated by earlier workers[5,6] and, from the results obtained, it was suggested that the oxides of manganese and calcium were equivalent in their effect upon the activity of ferrous oxide. However, on theoretical grounds it is difficult to see why such an equivalence should exist, indeed in binary silicate melts the activity of manganese oxide is greater at all concentrations than that for lime and is located closer to that for ferrous oxide. Further, a marked deviation from ideality occurs in FeO–CaO system while ferrous and manganese oxides form ideal solutions, and it is often assumed that ferrous oxide behaves ideally in the $FeO–MnO–SiO_2$ system. On this basis it would be expected that the replacement of lime by manganese oxide in silicate melts would cause the activity of ferrous oxide to approach more closely to ideal behaviour. The present investigation was designed to examine whether or not this argument is valid.

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Experimental method

Apparatus

Melts of about 5 g, held in open-topped pure iron crucibles, were equilibrated with hydrogen–steam–argon mixtures.[1] It was necessary to place the gas

inlet probe so that it just broke the slag surface. To achieve this the probe was located by means of an electrical contact device.[7]

Method

The melts were reacted for 4 h. Occasional melts were assayed at this stage and then further reacted for a 2–4-h period to ascertain that equilibrium had indeed been reached. No significant difference was found in the final composition of any of these melts and it was concluded that the 4-h period was satisfactory. However, the presence of two high melting-point silicates in the mixture required a prolonged melting and homogenization period before the introduction of the gas mixture.

The possibility of errors arising from both incorrect probe location and lack of homogeneity was minimized by adopting a pre-melting treatment. The reaction crucible and its contents were held at the reaction temperature under a nitrogen atmosphere for at least 2 h. The melt was then allowed to solidify and the crucible was withdrawn from the furnace in the normal manner. Before the start of the equilibration run the probe-tip could then be located relative to the molten slag surface with reasonable accuracy by inspection of the slag line and the height of the solid surface.

Frequent checks were performed on melts in the FeO–SiO_2 and FeO–CaO–SiO_2 systems and the results were compared with previously obtained data.[1,8] A satisfactory agreement was obtained.

Preparation of materials

Stock mixtures of calcium and ferrous silicates were prepared as described previously.[1] The stock manganese silicate mixture was prepared by fusion of pure manganese oxide powder (99·9%MnO) with fine sand in a platinum crucible at 1350°C. The crucible was held at temperature for at least 4 h before its contents were cast on to a cold steel plate. The material was then crushed and analysed. The manganese oxide contents of the prepared silicate were in the range 50–60%MnO. During the preparation a small loss of manganese was detected; this was probably due to volatilization and possibly by solution in the platinum dish.

Methods of analysis

The ferrous and ferric oxide contents of the reacted melts were determined as described previously.[1] Silica, manganese oxide, and lime were initially assayed by normal wet methods and subsequently by spectrophotometric techniques. In the latter case, silica was determined by the molybdenum-blue method of Mullin and Riley,[9] manganese oxide as the permanganate ion,[10] and calcium oxide was determined, after removal of iron and manganese, by titration of the buffered solution with ethylenediaminetetraacetic acid using Eriochrome Black T as indicator. Towards the end of the investigation calcium was determined with a flame photometer calibrated against standard calcium solutions.

All assays were performed in duplicate or triplicate and with the exception of ferric oxide are considered to be correct to within ±0·25%. The accuracy in the case of ferric oxide is considered to be ±0·4% since the value was obtained as the difference in two titrations. The total analysis was considered satisfactory provided the sum of the determined components fell within the range 99·0–101·0%. A few melts which on this basis were found to be unsatisfactory were reassayed.

Results

The composition range studied in the previous investigation[1] was limited to slags slightly less acid than the pseudo-binary join $CaO/SiO_2=1$ by the liquidus boundaries for the FeO–CaO–SiO_2 system at the experimental temperatures. In the present case the field amenable to investigation is restricted by the liquidus limits of the quaternary system FeO–CaO–MnO–SiO_2. Apart from an investigation by White[11] of the phase relationships at about 960°C on certain planes in this system there are no experimental data for the composition limits. Indeed the equilibrium data for the FeO–MnO–SiO_2 system are contradictory[12] and it is not considered satisfactory to make a linear extrapolation in the appropriate temperature range between the FeO–CaO–SiO_2 and FeO–MnO–SiO_2 liquidus compositions. Thus it is impossible to locate with any accuracy the range of liquid melts in the quaternary system.

However, the evidence available does suggest that, relative to the liquidus limits in the ternary system at 1300°C those for the quaternary are expanded at low $CaO+MnO$ contents and are contracted at high contents. It was decided accordingly to investigate melts containing 4, 7, and 12 mole-%MnO within the liquid range for the FeO–CaO–SiO_2 system. No evidence was obtained either from the appearance of reacted material or from the consistency of the resulting data to suggest that the true liquidus limits in fact had been exceeded.

For comparison with the data previously obtained for the FeO–CaO–SiO_2 system[1] the present study was confined to the three experimental temperatures 1265° 1305° and 1365°C. With 4 and 7 mole-% manganese oxide additions the field of investigation covered the activity range 0·1–0·7 but attempts to locate the 0·1 activity curve at 1265°C were unsuccessful, probably due to the close proximity of the liquidus surface. Similarly, with 12 mole-% manganese oxide present consistent results were limited to activities greater or equal to 0·2, at the higher temperatures and 0·3 at 1265°C. The investigation was not extended beyond activities of 0·7 since such data would be of only theoretical interest and is not pertinent to steelmaking conditions. Further the ferrous oxide saturation surface in this range is again not clearly defined.

The compositions and the corresponding ferrous oxide activity values for 75 slags for which complete analyses are available are recorded in Table I. From these data the iso-activity contours in the FeO–$(CaO+MnO)$–SiO_2 system are drawn on a mole percentage basis for the three temperatures examined (Figs.1–3). The intercepts of these contours along the FeO–SiO_2 binary edge are taken from the data for the binary system[1,8] and the activity contours for the MnO-free melts are included for the purpose of comparison.

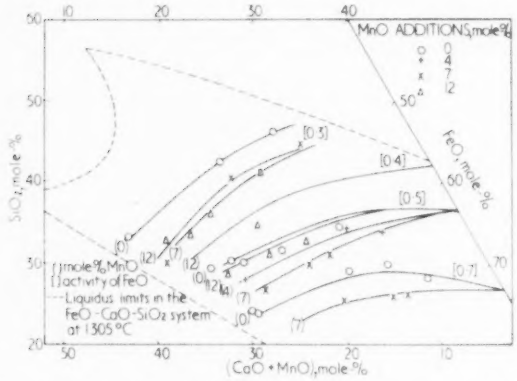
Melts containing 4 and 7% manganese oxide were investigated initially and it appears from these data that the displacement of the iso-activity curves from the location of the corresponding curves in the FeO–CaO–SiO_2 system was approximately a linear function

of the manganese oxide content. The starting compositions for a large number of melts containing 12 mole-% MnO were selected on this basis. However, after equilibration it was found that no increase in iron oxide had occurred which suggested that the linear relationship did not extend to the higher manganese oxide addition. The starting compositions were then moved to lower iron oxide contents until a reasonable increase in the equilibrium ferrous oxide content of the melt was obtained. It was thus found that the isoactivity contours at this concentration were located between those for 0 and 7% manganese oxide additions. The only exception to this statement is the 0·5 activity curve at 1365 C which is located at slightly higher ferrous oxide contents than the corresponding 7 mole-% curve.

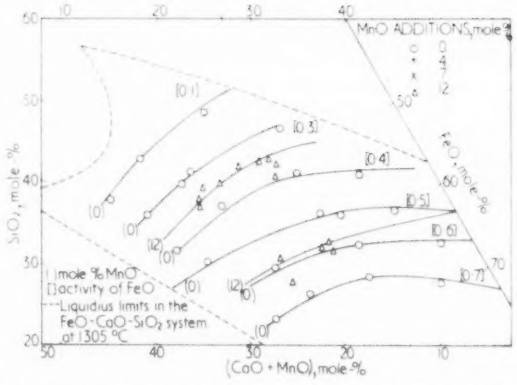
The compositions recorded in Table I are for melts in which an increase in iron oxide content of from

TABLE I Equilibrium data

Melt no.	Temp., °C	Analysis Weight, % x_{FeO}	FeO	Fe_2O_3	SiO_2	MnO	CaO	Mole, % FeO	SiO_2	MnO	CaO
1	1261	0·700	64·8	1·8	23·1	7·6	2·7	63·1	26·3	7·4	3·2
2	1264	0·702	63·4	2·0	22·8	7·1	4·7	61·7	25·8	6·8	5·7
3	1265	0·703	58·2	2·6	22·4	8·2	8·6	56·7	25·2	7·8	10·3
4	1361	0·704	64·7	1·6	23·7	7·3	2·7	62·8	26·9	7·0	3·3
5	1360	0·702	60·8	2·9	22·2	7·6	6·5	59·9	25·0	7·2	7·9
6	1360	0·704	58·8	3·6	20·9	7·4	9·3	58·3	23·5	7·0	11·2
7	1268	0·507	59·5	1·4	30·4	4·4	4·3	56·7	33·9	4·2	5·2
8	1270	0·530	58·8	2·3	30·0	4·6	4·3	56·8	33·7	4·4	5·1
9	1263	0·505	54·8	2·2	30·8	4·1	8·1	52·4	34·1	3·9	9·6
10	1262	0·505	47·9	2·1	25·9	4·4	19·7	45·1	28·0	4·1	22·8
11	1260	0·503	54·2	2·5	27·7	9·1	6·5	52·7	30·9	8·6	7·8
12	1250	0·497	52·9	2·4	26·8	8·9	9·0	51·1	29·8	8·3	10·8
13	1260	0·503	49·7	2·8	24·5	8·5	14·5	48·0	27·0	7·9	17·1
14	1274	0·517	50·8	2·0	29·4	14·0	3·8	49·2	32·8	13·3	4·7
15	1267	0·513	48·2	1·9	28·0	14·0	7·9	46·3	31·0	13·2	9·5
16	1271	0·516	45·1	1·9	26·1	14·4	12·5	43·0	28·8	13·5	14·7
17	1301	0·498	54·3	2·0	28·2	13·2	2·3	52·7	31·7	12·7	2·9
18	1310	0·510	53·4	1·9	29·1	12·7	2·9	51·6	32·6	12·2	3·6
19	1307	0·515	52·9	1·9	28·8	13·9	2·5	51·3	32·3	13·2	3·2
20	1304	0·507	51·7	1·9	24·9	15·7	5·8	50·2	27·9	15·0	6·9
21	1309	0·502	49·1	2·3	27·7	13·3	7·6	47·6	30·7	12·4	9·3
22	1363	0·506	57·4	1·1	31·6	3·9	6·0	54·2	35·2	3·6	7·0
23	1366	0·506	53·3	1·9	31·4	4·3	9·1	50·7	34·7	4·0	10·6
24	1364	0·500	47·9	2·0	27·6	4·3	18·2	44·9	30·0	4·0	21·1
25	1361	0·504	46·0	1·8	26·7	4·3	21·2	42·9	28·8	3·9	24·2
26	1373	0·510	56·0	1·1	27·9	8·7	6·3	53·2	31·0	8·2	7·6
27	1368	0·514	54·3	2·0	30·8	9·7	3·2	52·4	34·4	9·2	4·0
28	1374	0·510	52·6	2·0	26·5	8·1	10·8	50·3	29·3	7·6	12·8
29	1374	0·509	50·5	2·5	24·6	8·9	13·5	48·7	27·1	8·3	15·9
30	1367	0·553	56·2	3·2	26·9	11·5	2·2	55·8	30·4	11·0	2·8
31	1368	0·554	55·7	2·1	24·8	13·4	4·0	54·3	28·0	12·8	4·9
32	1370	0·508	55·3	3·3	28·6	12·8	3·3	51·9	32·0	12·1	4·0
33	1368	0·556	54·2	3·6	27·0	11·4	3·8	54·1	30·3	10·9	4·7
34	1361	0·503	53·9	2·3	27·0	14·4	2·4	52·7	30·4	13·8	3·1
35	1366	0·505	51·2	4·6	23·8	13·7	6·7	51·9	26·8	13·2	8·1
36	1265	0·403	44·6	2·5	31·5	14·5	6·9	43·2	34·8	13·5	8·5
37	1267	0·406	40·0	2·6	30·8	15·5	11·1	38·8	33·7	14·4	13·1
38	1365	0·425	50·1	2·0	32·2	11·5	4·2	48·4	35·8	10·8	5·0
39	1370	0·428	45·1	1·4	31·9	14·1	7·5	42·8	35·2	13·2	8·8
40	1362	0·415	41·0	3·5	31·0	15·0	9·5	40·6	34·1	14·0	11·3
41	1265	0·304	45·8	0·9	40·7	7·2	5·4	42·6	44·4	6·7	6·3
42	1261	0·303	40·6	1·2	37·5	7·2	13·5	37·5	40·3	6·6	15·6
43	1262	0·303	39·1	0·9	28·0	8·3	23·7	35·6	29·8	7·5	27·1
44	1265	0·305	42·0	2·0	37·4	13·6	5·0	40·2	41·2	12·7	5·9
45	1261	0·301	39·4	1·9	33·2	14·7	10·8	37·5	36·2	13·6	12·7
46	1264	0·304	36·2	2·6	31·1	14·7	15·2	34·3	32·9	13·2	19·6
47	1305	0·304	43·6	1·7	38·2	13·0	3·5	41·5	42·3	12·1	4·1
48	1310	0·304	43·0	3·0	36·6	14·8	2·6	42·2	40·5	14·0	3·3
49	1300	0·302	42·9	1·2	39·1	12·9	3·9	40·4	42·9	12·1	4·6
50	1302	0·302	40·6	2·5	39·0	13·5	4·4	39·4	42·7	13·6	5·3
51	1313	0·306	39·7	1·7	38·5	13·0	7·1	37·6	41·9	12·1	8·4
52	1300	0·296	37·9	1·4	34·9	13·3	12·5	35·5	37·7	12·2	14·6
53	1305	0·295	37·8	1·8	34·6	12·8	13·0	35·6	37·4	11·8	15·2
54	1308	0·303	37·3	2·1	36·8	13·8	10·0	36·7	39·9	12·7	11·7
55	1309	0·305	36·7	2·0	36·6	13·2	11·5	35·1	39·3	12·3	13·5
56	1369	0·303	42·5	0·7	40·7	8·0	8·1	39·1	44·1	7·4	9·4
57	1363	0·301	42·9	0·7	40·2	7·8	8·4	39·4	43·7	7·1	9·8
58	1366	0·301	42·6	0·8	40·4	7·5	8·7	39·2	43·8	6·9	10·1
59	1360	0·303	41·7	0·8	38·4	7·4	11·6	38·2	41·6	6·8	13·4
60	1365	0·301	39·7	1·3	38·1	8·2	12·7	36·8	41·1	7·4	14·7
61	1365	0·302	39·5	0·8	33·1	9·0	17·6	36·1	35·5	8·2	20·2
62	1372	0·297	38·7	1·0	33·4	10·2	16·7	35·5	36·0	9·3	19·2
63	1363	0·301	37·5	0·9	30·0	7·7	23·9	34·0	31·8	6·9	27·3
64	1366	0·310	42·1	1·0	39·7	12·7	4·5	39·5	43·4	11·8	5·3
65	1363	0·306	39·7	1·0	34·8	13·6	10·9	37·0	37·8	12·5	12·7
66	1366	0·304	36·9	2·5	36·7	13·4	10·5	35·5	39·9	12·4	12·2
67	1367	0·201	33·2	2·4	39·7	15·2	9·5	32·0	42·9	13·9	11·2
68	1370	0·202	29·9	2·8	37·3	15·2	14·8	29·1	39·9	13·9	17·1
69	1366	0·101	25·6	1·1	50·4	4·0	18·9	23·1	52·3	3·5	21·1
70	1360	0·101	25·3	0·9	41·3	4·4	28·1	22·5	42·6	3·8	31·1
71	1363	0·101	24·3	0·9	38·2	4·4	32·2	21·6	39·2	3·8	35·4
72	1368	0·102	31·0	1·2	49·3	8·0	10·5	28·5	52·3	7·2	12·0
73	1359	0·100	31·6	1·1	39·5	8·9	18·9	28·8	41·8	8·0	21·4
74	1368	0·101	28·9	1·0	39·7	7·4	23·0	26·1	41·5	16·6	25·8
75	1367	0·102	29·2	0·9	34·1	8·7	27·1	26·2	35·7	7·7	30·4


MnO ADDITIONS, mole %
SiO₂, mole %
FeO, mole %
(CaO + MnO), mole %
[] mole % MnO
[] activity of FeO
Liquidus limits in the FeO-CaO-SiO₂ system at 1305 °C

1 *Ferrous oxide iso-activity curves in the* FeO–(CaO + MnO)–SiO_2 *system at 1265°C*


MnO ADDITIONS, mole %
SiO₂, mole %
FeO, mole %
(CaO + MnO), mole %
[] mole % MnO
[] activity of FeO
Liquidus limits in the FeO-CaO-SiO₂ system at 1305 °C

2 *Ferrous oxide iso-activity curves in the* FeO–(CaO + MnO)–SiO_2 *system at 1305°C*

2 to 6% was found. The compositions of melts which showed no such increase are not shown, but these melts were taken into consideration in the construction of the iso-activity curves. For a given silica concentration at any specific activity the curve should not lie closer to the FeO apex of the system than the position of a melt which did not increase in iron oxide content.

The previous investigation of the FeO–CaO–SiO_2 system revealed that the ferrous oxide activity was markedly dependent on temperature whereas no temperature effect could be detected in the binary ferrous silicate system. A variation of activity with temperature is again apparent in the results for the quaternary system FeO–CaO–MnO–SiO_2. The equilibrium compositions at any activity level for each of the three experimental temperatures are fitted by smooth curves. The curves for a given activity value with varying manganese additions and temperature again extrapolate back to a single point on the binary edge. In general the variation of activity with temperature in the quaternary melts is smaller than that reported in the FeO–CaO–SiO_2 system.

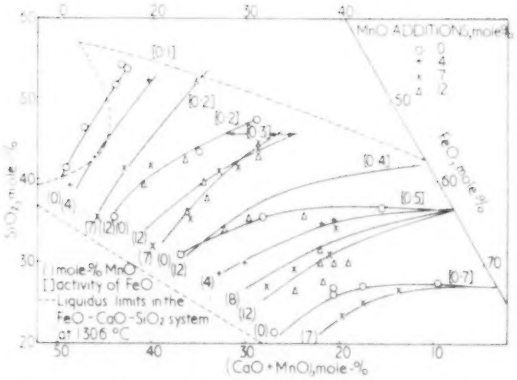
The results at the three experimental temperatures in the ternary system were best fitted at the 0·6 activity level by a smooth curve (Fig.4 of ref.1). At higher activities the iso-activity curves were displaced to higher ferrous oxide contents with increasing temperature whereas the reverse condition applied at activities lower than 0·6. Similar behaviour was observed in the presence of manganese oxide but it was found that this reversal in temperature dependence was displaced to lower activity values with increasing manganese oxide additions. That is, the activity data for the three experimental temperatures are best fitted by a single curve at the 0·5 and 0·4 values with respectively 7 and 12 mole-% manganese oxide present. In the lower activity range the slope of the iso-activity curves for the 12 mole-% manganese oxide addition differ significantly from the slope at lower concentrations. At the 0·3 activity level the curves for the 7 and 12 mole-% additions converge with increasing silica and extrapolation to the silica saturation boundary in the FeO–CaO–SiO_2 system suggests that the curves intersect. This effect is considered to result from the change of location of the silica saturation surface with varying manganese oxide additions.

When the final analyses of the melts were compared with the compositions of the starting mixtures corrected for the increase in iron oxide, the manganese oxide content was found to have decreased. The loss was found to increase relative to the manganese oxide content of the initial mixture and to be in the range 0·5–2·0%. A number of melts were therefore reassayed for manganese oxide by alternative methods but no significant difference was detected in the manganese oxide concentrations. In addition the total analyses were not consistently low, suggesting that all the manganese present had been determined. It was considered that the loss may have resulted from absorption of manganese in the iron crucible during the reaction period. Reacted crucibles were therefore cleaned of adherent slag and the inner surface below the slag line was removed to a depth of 0·03 in. Analysis of this material gave a mean value of 0·07% manganese whereas analysis of the unused crucibles gave a figure of 0·03%. The difference is within the limits of the experimental analytical accuracy and is not considered to be significant. However, if this difference is real and the manganese content of the whole crucible had increased by this amount it would still be far from sufficient to account for the total manganese loss. It is possible that manganese was lost from the melts by volatilization and this tendency had been noticed in the preparation of the manganese silicate master-mixtures. This suggestion is further supported by the appearance of a dark deposit at the cooled ends of the furnace tube. A satisfactory analysis of the deposit was not possible since it was absorbed into the porous surface of the refractory and could not be collected.

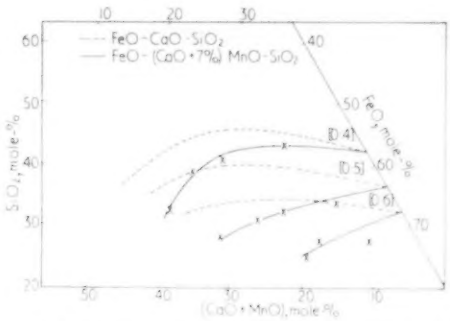
Variation of the ferric oxide content of equilibrium melts

The accuracy of the determination of ferric oxide, relative to the small number of ferric ions in the melt, is low, and there are insufficient data at any temperature and manganese oxide concentration to justify a detailed examination of the variation of the ferric to ferrous ion ratio. However, general observations can be made by comparison of the ferric oxide contents given in Table I with those for the FeO–CaO–SiO_2 system.

In the present investigation the ferric oxide content varied from 0·7–4·6%, the higher concentrations being found at the higher activity levels. No significant



3 *Ferrous oxide iso-activity curves in the* FeO–(CaO + MnO)–SiO_2 *system at 1365°C*



4 *Ferrous oxide iso-activity curves in the* FeO–(CaO + MnO)–SiO_2 *system at 1600°C*

variation was observed with temperature. These values are somewhat greater than those previously reported for the ternary melts, the difference being most pronounced in the presence of 12 mole-% manganese oxide. This observation is at variance with the results of other workers[13–15] and this point warrants further investigation.

Derivation of the 1600°C iso-activity curves for the FeO–(CaO + MnO)–SiO_2 system

It has previously been shown that at constant composition the logarithm of the activity of ferrous oxide in the FeO–CaO–SiO_2 system is a linear function of temperature. Thus the ferrous oxide iso-activity curves were obtained at 1600°C by linear extrapolation from the experimental temperature range. A similar procedure has been adopted for the present results and the iso-activity curves so obtained are shown together with those for the ternary system in Fig.4.

Since a linear extrapolation is employed it is obvious that the values of activity and composition at which the curves for the three experimental temperatures are superimposed will be unaffected by the temperature adjustment. When the temperature is extended linearly it is found that the extrapolation lines are convergent, such that the range of activities at 1600°C is restricted in relation to those investigated. Thus with 12 mole-% additions of manganese oxide the extrapolation of experimental data yields activities varying in the limited range from 0·36 to 0·41.

DISCUSSION

The addition of calcium oxide to molten silicates causes a marked increase in the activity coefficient of ferrous oxide. The present investigation has shown that the replacement of lime by manganese oxide lowers the activity coefficient to values intermediate to those found in the binary silicate and in the FeO–CaO–SiO_2 ternary melts. A similar observation applies to the extrapolated iso-activity curves at 1600°C. The displacement between the latter and the corresponding curves of Elliott[4] and Turkdogan and Pearson[5] is greater than that previously found for the MnO-free melts.

It has been suggested that manganese and calcium oxides have equivalent effects upon the activity of ferrous oxide[2,5,6] whereas the present results show clearly that this is not true on either a molar or a weight percentage basis. Further the extrapolated iso-activity curves at 1600°C suggest that the differences increase with increasing temperature. It is recognized that the location of the iso-activity curves at 1600°C for the melts containing manganese oxide is tentative and that their positions are less accurately determined than the corresponding curves for the ternary system. However, a considerable change from the linear temperature relationship would be required to cause the two sets of data to converge at the higher temperature. No deviation from a linear temperature dependence was found in the experimental results and there seems no reason to suggest that such a change should occur with increasing temperature.

The suggested equivalence of lime and manganese oxide was made initially on the basis of the results of Chipman *et al.*[2,3] However, these melts also contained magnesia and it was suggested that all three basic oxides were in fact equivalent in their effect on the activity of ferrous activity on a molar basis. In view of the present results it could be argued that the activity is lowered by magnesia, such that the sum effect of the manganese and magnesium oxide contents were equivalent to an equal concentration of lime in Chipman's melts. However, the activity of ferrous oxide has recently been determined by Fischer and Spitzer[16] in melts consisting primarily of calcium, magnesium, and iron oxides. In the range 1520–1680°C the activity of ferrous oxide was raised by magnesium oxide relative to the values found in mixtures of lime and ferrous oxide. The experimental points are located between the curve obtained for FeO–CaO melts by Bishop *et al.*[6] and the line representing Raoult's Law.

Thus it would appear that both magnesia and manganese oxide raise the activity of ferric oxide although the composition ranges at which these effects are observed do not coincide, i.e. the magnesia data were obtained in basic melts whereas the manganese oxide data are restricted to more acid compositions. However, the displacement between the iso-activity curves for melts containing manganese oxide relative to the curves in the FeO–CaO–SiO_2 system increases with increasing basicity within the composition range studied. There is no evidence to suggest that this trend should be reversed at higher basicities.

Turkdogan and Pearson[5] have also suggested that the effects of the three basic oxides are equivalent but their data were obtained from melts containing phosphorous pentoxide and alumina in addition to the five

TABLE II Ionic equation data

No.	CaO/SiO_2	$N_{Fe^{2+}}$	$N_{Ca^{2+}}$	$N_{Mn^{2+}}$	$N_{SiO_3^{2-}}$	$N_{O^{2-}}$	$\gamma_{FeO(B)}$	x_{FeO}(1365°C) exp.	x_{FeO}(1365°C) calc.	x_{FeO}(1600°C) exp.	x_{FeO}(1600°C) calc.
1	1:1	0·442	0·441	0·117	0·557	0·443	0·80	0·20	0·29	...	...
2	1:1	0·519	0·370	0·111	0·482	0·518	0·86	0·33	0·39	0·40	0·48
3	1:1	0·619	0·278	0·103	0·381	0·619	0·96	0·47	0·54	0·50	0·62
4	1:1	0·658	0·181	0·161	0·342	0·658	0·98	0·50	0·53	...	...
5	1:1	0·551	0·275	0·174	0·449	0·551	0·89	0·40	0·40	...	...
6	1:1	0·485	0·333	0·182	0·515	0·485	0·83	0·30	0·32	...	...
7	1:1	0·433	0·379	0·188	0·567	0·433	0·78	0·20	0·25	...	...
8	2:3	0·520	0·351	0·129	0·721	0·279	0·71	0·20	0·22	...	...
9	2:3	0·575	0·302	0·123	0·640	0·360	0·73	0·29	0·29	0·40	0·37
10	2:3	0·700	0·191	0·109	0·449	0·551	0·90	0·48	0·49	0·50	0·56
11	2:3	0·726	0·105	0·169	0·411	0·589	0·91	0·50	0·47	...	...
12	2:3	0·633	0·181	0·186	0·552	0·448	0·80	0·40	0·33	...	...
13	2:3	0·574	0·229	0·197	0·639	0·361	0·73	0·30	0·30	...	...
14	2:3	0·521	0·273	0·206	0·718	0·282	0·70	0·20	0·18	...	...
15	1:2	0·578	0·284	0·138	0·842	0·158	0·70	0·20	0·15	...	...
16	1:2	0·647	0·225	0·128	0·704	0·296	0·72	0·31	0·25	0·40	0·32
17	1:2	0·762	0·127	0·111	0·477	0·523	0·86	0·48	0·45	0·50	0·50
18	1:2	0·775	0·051	0·193	0·550	0·450	0·89	0·50	0·35	...	...
19	1:2	0·694	0·113	0·207	0·612	0·388	0·75	0·40	0·27	...	...
20	1:2	0·638	0·155	0·216	0·722	0·258	0·70	0·30	0·15	...	...

components previously considered. In this case the system is so complex that a number of opposing effects will occur and it is difficult to analyse the effect of each oxide on the activity of ferrous oxide.

The effects of manganese and magnesium oxides are in line with the behaviour which would be expected from theoretical considerations and which will be dealt with in a later paper.

It is interesting to examine the present results with respect to the attainment of the equilibrium distribution of the various elements under open-hearth steelmaking conditions. It is generally recognized that, with the exception of carbon, these distributions are at, or very close to, equilibrium by the end of the refining period, but the oxygen concentration in the metal is greater than that calculated from the carbon–oxygen equilibrium data. Further, it has been shown that the metal oxygen content calculated from the ferrous oxide iso-activity curves of Chipman *et al.* and of Turkdogan and Pearson is considerably greater than that actually present in the metal at this stage.[17,18]

It is unfortunate that the liquidus limits in the present experimental temperature range precluded the examination of slag compositions typical of those encountered in practice, but it is clear that at low ferrous oxide contents the value of α_{FeO} is considerably lower than was suggested by the earlier investigations. Thus if the metal–oxygen contents were calculated from an extrapolation of the present iso-activity contours the values obtained would lie closer to those found in practice.

Application of an ionic expression for the activity of ferrous oxide

To avoid the necessity of consulting a number of activity-composition diagrams to determine the activity of ferrous oxide in complex melts it would be useful if the activity could be derived quickly from a simple equation. It has been shown that the activity in the ternary FeO–CaO–SiO_2 system can be computed with reasonable accuracy by means of the following equation:

$$RT \ln \alpha_{FeO} = RT \ln N'_{Fe} N'_{O} + RT \ln \gamma_{FeO(B)} + xN'_{Fe}N'_{Ca}N'_{SiO_3}$$

where $\gamma_{FeO(B)}$ is the activity coefficient in the FeO–SiO_2 system at the same silica concentration as the complex slag considered, and x is an arbitrary constant equal to 19000 at 1365°C and 30000 at 1600°C.

The activities calculated from this equation at 1365°C are compared with the experimentally determined values for manganese oxide additions of 7 and 12 mole-% in Table II. The agreement is reasonably good except at the ratio of CaO/SiO_2=0·5 with 12 mole-% manganese oxide present. In this case the lime concentration is less than that of manganese oxide and the experimental melts approach closer to the FeO–MnO–SiO_2 system than to the FeO–CaO–SiO_2 system.

Table II also contains a comparison of values calculated for 1600°C with those obtained by extrapolation of the experimental data for melts containing 7 mole-% manganese oxide. In this case the agreement is somewhat less satisfactory but, as stated earlier, these extrapolated curves are not considered to be located as accurately as those for the manganese oxide-free melts.

It is interesting to note that the equation does not contain a term involving the manganese ion concentration and yet the fit of the calculated values is almost as good as that in the ternary system. This suggests that over most of the composition range to which the equation is applicable manganese oxide acts as an inert diluent. This would be the case for instance if the activity of ferrous oxide in manganese silicates was almost ideal. The equation could be made to fit the experimental results still more closely if the manganese-ion concentration raised to a low power were included in the final term. However, this refinement is not considered worth including at this stage of the development of the equation.

CONCLUSIONS

The activity of ferrous oxide is lowered by the presence of manganese oxide relative to the values found in the FeO–CaO–SiO_2 system but the magnitude of the change is not a linear function of the manganese oxide concentration.

Within the present experimental temperature range the oxides of manganese and calcium are not equivalent on either a molar or a weight percentage basis in their effect upon the activity of ferrous oxide. Linear extrapolation of the experimental data suggests that this observation is also pertinent to higher temperatures.

The ferrous oxide activity in the quaternary system $FeO–CaO–MnO–SiO_2$ can be computed with reasonable accuracy by means of an empirical equation when manganese oxide is considered as an inert diluent. This is regarded as indirect evidence that mixtures of manganese and ferrous silicates behave almost ideally, whereas mixtures of calcium and ferrous silicates show pronounced deviation from this law.

ACKNOWLEDGMENTS

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A thermodynamic study of dilute solutions of sulphur in liquid iron, cobalt, and nickel, and binary alloys between these metals

C. B. Alcock and L. L. Cheng

SYNOPSIS

A study has been made of the thermodynamic properties of dilute solutions of sulphur in liquid iron, cobalt, and nickel at 1540°C. Measurements have also been made of the behaviour of sulphur in the liquid alloys iron–cobalt, cobalt–nickel, and nickel–iron at the same temperature. The experimental technique consisted of bringing small beads of pure metals and alloys to equilibrium with gas mixtures of H_2/H_2S of controlled ratio. The sulphur content of the beads was analysed by the oxygen combustion method.

The results in the alloy studies for the variation of the activity coefficient of sulphur across the whole composition range of the binary alloys are discussed in terms of a simple theory, and are compared with those for other dilute solutes in these alloys. 1782

INTRODUCTION: THE BINARY SYSTEMS

THE FREE ENERGY of solution of small amounts of sulphur in liquid iron has been established by Chipman, Sherman, and Elvander,[1] the corresponding data for sulphur in liquid cobalt and nickel being still somewhat uncertain. The gas equilibria

$$[S] + H_2 \rightleftharpoons H_2S \quad K = \frac{pH_2S}{pH_2\,[\text{at-}\%S]}$$

have therefore been studied at 1540°C using the equilibration technique described in a previous paper[2] where it was shown that the partial free energy of solution of sulphur in dilute solution in liquid nickel was about 2·5 kcal *more* negative than that in supercooled iron at 1500°C, and about the same amount *less* negative in the case of liquid cobalt compared with iron. The present research has confirmed this sequence of stabilities for the dilute solutions of sulphur in the liquid iron-group metals. It has further been shown that whereas sulphur departs measurably from Henry's law in dilute solution in liquid iron, the solutions in liquid nickel conform to this law up to at least 6 at-%.

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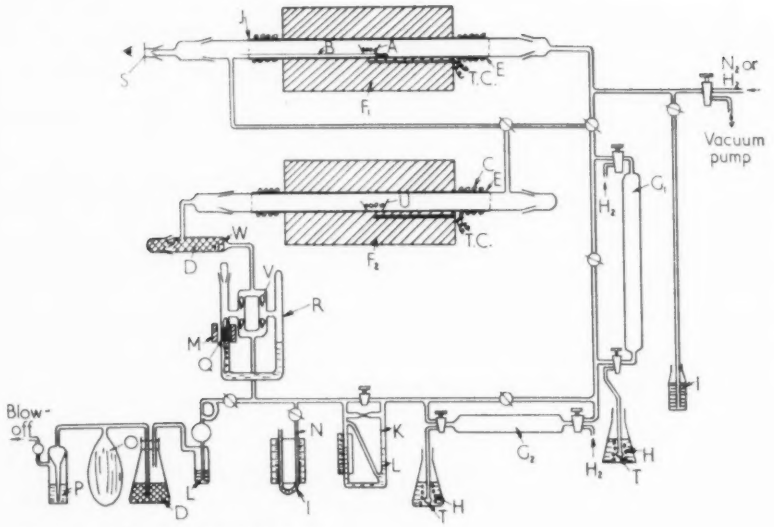
A Metallic beads for equilibrium studies
B alumina 'gutter'
C water cooling coil
D drying agent (Anhydrone)
E alumina tube
F_1 equilibrium reaction furnace
F_2 H_2S gas producing furnace
G_1 large gas sampling volume
G_2 small gas sampling volume
H $Zn(Ac)_2$ solution
I mercury
J glass mullite joint (Araldite)
K flow-rate meter
L dibutyl phthalate
M electromagnet
N Hg manometer
O collapsible H_2 gas reservoir
P strong NaOH solution
Q soft iron in glass casing
R gas circulation pump
S sighting window
T gas bubbling bulb
U Cu/Cu_2S for generating H_2S gas
V glass non-return valves
W glass wool



1 *Two-furnace gas circulation apparatus for gas/liquid equilibrium studies*

In the liquid cobalt solvent, the maximum sulphur content which was studied was about 1 at-% and no deviation from Henry's law could be found.

TERNARY SYSTEMS

Alcock and Richardson[2] have recently proposed that the approximate solution of the ternary Gibbs-Duhem equation for the activity coefficient of a dilute solute X in a binary liquid solvent A–B

$$\log \gamma_{X(A-B)} = N_A \log \gamma_{X(A)} + N_B \log \gamma_{X(B)} - \frac{\Delta G^{XS}(A-B)}{4{\cdot}575T}$$

should apply when $\log \gamma_{X(A)}$ is not very different from $\log \gamma_{X(B)}$. This implies that the coordination shell of an X atom in the solution is made up of A and B atoms in the proportions of their respective atom fractions in the solution.

The results for the activity coefficient of sulphur in the alloys which were studied in this research agree quite well with those calculated from the equation quoted above.

EXPERIMENTAL APPARATUS AND PROCEDURE

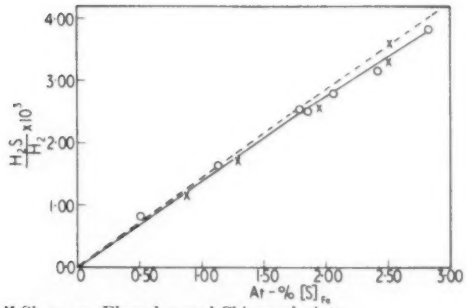
The apparatus, shown in Fig.1, consisted of a gas recirculation system incorporating two platinum-wound furnaces in series. The lower furnace, F2, was used to heat an alumina boat containing liquid $Cu–Cu_2S$ having sufficient sulphur content to supply sulphur, via the gas phase in a H_2/H_2S mixture, to the eight metal beads which were held in an alumina container heated by the upper furnace F1. The metal beads weighed between 500 and 900 mg each. Morgan recrystallized alumina tubes ΔRR, were used as reaction tubes. The beads and the sulphur source were introduced into the furnaces against a fast flowing stream of pure argon. The apparatus was then evacuated, leak tested, and filled with hydrogen at the beginning of an experiment and the gas was then circulated by the pump *R*. The experiments each lasted about 14 h (overnight) thus allowing sufficient time to permit the attainment of equilibrium, which had previously been shown by radiochemical methods to require about 5 h. At the end of a run, the beads were quickly removed from F1 under a nitrogen atmosphere and a gas sample was extracted and analysed for the H_2/H_2S ratio. The H_2S content of the sample was measured by absorption in 5% zinc acetate solution when zinc sulphide was precipitated. Excess N/100 iodine solution was then added followed by 10 ml concentrated HCl. The unreacted iodine was titrated against standard sodium thiosulphate solution using starch as an indicator. This method is simpler to use than absorption of the H_2S in sodium hypochlorite solution.[3]

MATERIALS

The pure iron (99·96%) used in the research was super Hipperm iron, pure nickel (99·95%) shot was obtained from the Mond Nickel Company, and pure cobalt, with a total metallic impurity of less than 0·009 wt-%, from Messrs Johnson Matthey, Ltd. The sulphur was purified by distillation before being used together with high purity electrolytic copper to synthesize the cuprous sulphide for the sulphur source.

COMBUSTION ANALYSIS

The method of analysis which was used in these experiments was slightly different from that usually employed in the oxygen combustion procedure for the determination of sulphur in pure iron. It was found that the evolution of sulphur dioxide was very slow when nickel and cobalt beads were analysed by the conventional method, and alloying of the beads with copper before oxidation, which was found to speed up SO_2 evolution, was therefore adopted as a standard procedure. Each bead was wrapped in roughly its own weight of pure copper foil before being placed in the combustion boat, which was almost completely covered by a lid. The boat was then pushed into the combustion furnace under a stream of pure argon and after reaching 1350–1400°C was held in argon for a few minutes to allow completion of the formation of the liquid copper-transition metal alloy. The gas was then changed to oxygen at 500 cm^3/min and after an



X Sherman, Elvander, and Chipman's data
○ present results

2 *Plot showing 'Henry's law' behaviour of sulphur in liquid iron at 1540°C*

initial burning period of a few minutes, the flow rate was reduced to 250 cm^3/min for the rest of the analysis. The SO_2 which was evolved during combustion was absorbed in 10% ammonium acetate solution which was titrated continuously with N/100 iodine solution using starch as an indicator.[4] Each analysis took about 45 min to complete exclusive of the time required for the preliminary removal of sulphur from the combustion boat before the introduction of the alloy sample.

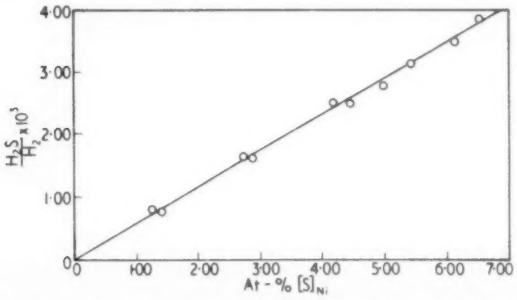
Since the oxygen combustion method is not quantitative,[5] some sulphur being lost as SO_3, the 'combustion factor' for the apparatus had to be established. This was done by using a standard steel sample, obtained as a powder, and carrying out some 56 analyses. Statistical analysis of the results showed that the 'combustion factor' i.e. the constant fraction of the sulphur content of a bead which could be measured iodimetrically was $0{\cdot}844 \pm 0{\cdot}04$. The rather wide error limits of the factor were disappointing, but as they could probably be attributed mainly to segregation in the sample, it is felt that although the absolute values of the sulphur contents of our samples may not have been established as well as might be hoped, nevertheless the relative values would be somewhat more reliable.

THE BINARY SYSTEMS

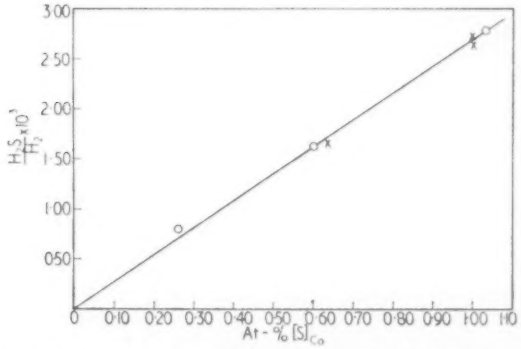
Results

The results for the pure liquid metals at a temperature of 1540°C are shown in Figs.2–4 and Table I.

The H_2S/H_2 ratios shown in the ordinate are not those measured in the gas analysis apparatus at room temperature, since the dissociation of H_2S at the high temperature is not insignificant,[6] and corrections to the



3 *Plot showing 'Henry's law' behaviour of sulphur in liquid nickel at 1540°C*



4 *Plot showing 'Henry's law' behaviour of sulphur in liquid cobalt at 1540°C*

room temperature analyses were made to calculate the ratios which are shown in the figure as those pertaining over the samples during equilibration.

It can be seen that our results for the Fe–S system agree quite well with those of Chipman and co-workers, and it could be argued that they show that sulphur deviates in a negative sense from Henry's law, but only slightly, in the range of sulphur contents which we have studied.

The Ni–S and Co–S results, however, can best be described as showing conformity to Henry's law even up to the surprizing amount of 6·5 at-% in the case of sulphur dissolved in liquid nickel.

The free energy of a solution of sulphur in these metals at 1540°C is thus −21400 cal for Co–S, −23500 cal. for Fe–S and −26800 cal for Ni–S, using 1 at-% as the standard state for sulphur for the reaction

$$H_2 + [S] \rightarrow H_2S.\ K = \frac{pH_2S}{pH_2} \cdot \frac{1}{[\text{at-}\%S]}$$

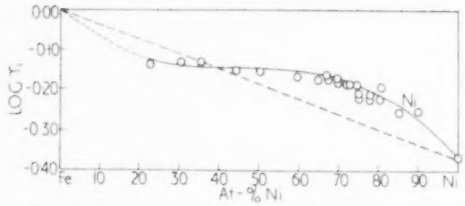
These results confirm the sequence and magnitudes of free energies previously suggested by Alcock and Richardson.

DISCUSSION

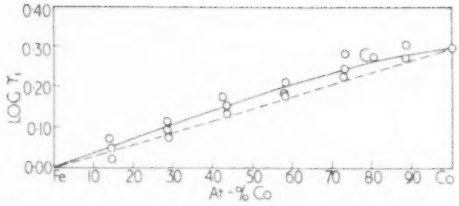
Since these experiments were only conducted at one temperature, the partial molar heats of solution, of

TABLE I Results for pure liquid metals (at 1540°C)

	Equilibrium observed	H_2S ratio $\times 10^3$/ H_2 corrected	At-% S
Fe–S	2·82	2·78	2·06
	1·64	1·62	1·14
	0·80	0·79	0·51
	3·88	3·81	2·83
	3·20	3·15	2·42
	2·54	2·50	1·80
	2·54	2·50	1·85
Co–S	2·82	2·78	1·03
	1·64	1·62	0·60
	0·80	0·79	0·263
	2·70	2·66	1·00
	1·68	1·66	0·635
	2·76	2·72	0·997
Ni–S	2·82	2·78	4·98
	1·64	1·62	2·73
	1·64	1·62	2·87
	0·80	0·79	1·28
	0·80	0·79	1·39
	3·88	3·81	6·50
	3·54	3·48	6·10
	3·20	3·15	5·41
	2·54	2·50	4·44
	2·54	2·50	4·16



5 *Effect of alloying nickel on the activity coefficient of sulphur in liquid iron at 1540°C*



6 *Effect of alloying cobalt on the activity coefficient of sulphur in liquid iron at 1540°C*

sulphur in the pure liquid metals cannot be rigorously calculated. However, it is generally found that the partial molar entropy of solution for such dilute solutions does not vary widely from one solvent to another and is usually between 2 and 5 entropy units. Thus for the standard state of 1 at-% in the condensed phase and the diatomic molecular species at one atmosphere pressure in the gas, for sulphur, it can be reasonably expected in the light of our results that the heats of solution of sulphur in liquid iron, cobalt, and nickel will be the same within ±3 kcal for 1 g-atom of sulphur i.e. −30000 cal.

It is interesting to compare the relative affinities of these metals for sulphur with other dilute solutes. Although the data in the literature are relatively sparse it is worth noting that nickel has a greater affinity for sulphur, silicon,[7] hydrogen,[8] silver[9] (as evidenced by greater solubility of silver in liquid nickel than in iron), copper,[10,11] and magnesium[9] in dilute solution and a smaller affinity for oxygen,[12] nitrogen,[13] and carbon.[14] Cobalt is sometimes intermediate between iron and nickel but the general pattern of its affinity to various solutes is not clear vis-à-vis the other members of this triad.

It would clearly be useful to expand our knowledge of these binary systems in the search for understanding of the thermodynamic properties. It is possible for example that where the solute atoms have essentially a positive charge, such as copper and silver, the affinity to nickel is greater than that to iron, and vice versa for a negatively charged solute such as oxygen. It is obvious from the results for the binary systems that the rule for relating the partial molar heat of solution of sulphur in the liquid metals to the heats of formation of the corresponding sulphides[15] cannot be applied significantly, since the partial molar heats have only been estimated to be the same within ±3 kcal, although it should be remembered that the heats of formation of the sulphides are FeS −35750, NiS −34980, CoS −36030 cal/g atom of sulphur, which are equally similar. However the rule gives no guide as to the relative stabilities of the dilute solutions and this is probably because it is only of value in such estimations where the difference in stabilities of the metal–sulphur systems is much larger.

THE TERNARY SYSTEMS

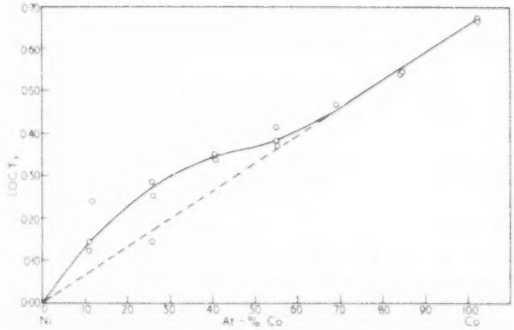
Results

The results for the liquid alloys of iron and nickel at 1540°C are shown in Fig.5 where the logarithm of the activity coefficient of sulphur, taking 1 at-% of sulphur dissolved in pure liquid iron as standard state, is shown as a function of the atomic fraction of nickel. The results for iron–cobalt alloys at the same temperature are shown in Fig.6, where the same standard state for sulphur has again been used. The 1% solution in pure nickel has been used as standard for Ni–Co (Fig.7). Since the evaluation of each activity coefficient was derived from two measurements of sulphur content, one in pure iron and the other in the alloy, the error was expected to be fairly large in view of the standard error in the determination of the 'combustion factor' for the sulphur analysis. The fact that the scatter is reasonably small, however, supports the contention that the chief source of error in the establishment of the combustion factor was segregation in the standard iron–sulphur alloy. It is difficult to assess the error in the value of each activity coefficient since duplicate alloys of the same composition were rarely made except in the iron–cobalt alloys, and these indicate a scatter in log γ_S of 0·02, or ±200 cal on the partial molar free energy of solution. These results are also given in Table II to demonstrate this point. The results for the binary systems probably offer the best guide to the accuracy of the measurements.

DISCUSSION

The theoretical equation for the activity coefficient of a dilute solute in a liquid binary solvent, which was mentioned above, should make it possible to predict the dependence of the activity coefficient of the solute, $\gamma x(A–B)$, on alloy composition from a knowledge of the activity coefficient of x in pure A, $\gamma x(A)$, that in pure B, $\gamma x(B)$ and the excess free energy of mixing of the A–B alloy, $\Delta G^{XS}(A–B)$ at the mole fractions N_A and N_B.

Since the activity coefficient of sulphur has been measured across the whole composition range in this study, it should be possible to reverse the procedure in this calculation and obtain values for the excess free energies of mixing of the solvent alloys from these results, and then compare these with direct measurements. It is found that the excess free energy of mixing



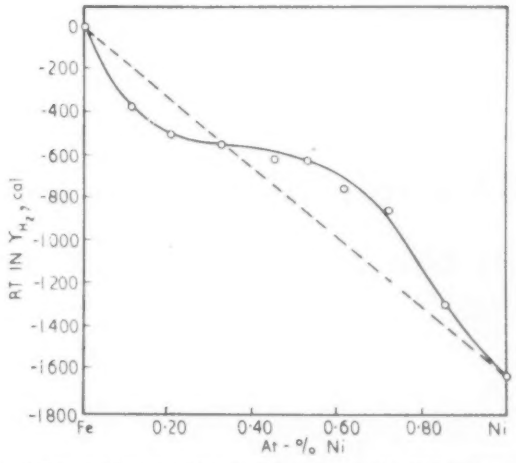
7 *Effect of alloying cobalt on the activity coefficient of sulphur in liquid nickel at 1540°C*

TABLE II Sulphur activity coefficients in iron–cobalt alloys

At.-% Co	At.-%S	γs	log γs
14·7	2·12	1·05	0·022
28·7	1·88	1·19	0·076
43·5	1·63	1·37	0·136
58·5	1·46	1·52	0·183
73·0	1·34	1·67	0·223
88·4	1·20	1·86	0·270
0·0	2·23	1·00	0·00
100	1·13	1·97	0·295
14·4	1·72	1·11	0·046
28·9	1·53	1·25	0·098
43·5	1·34	1·42	0·152
58·3	1·18	1·63	0·211
73·2	1·09	1·75	0·244
88·5	0·95	2·01	0·304
0·0	1·91	1·00	0·00
100	0·97	1·96	0·292
14·3	1·60	1·17	0·068
28·9	1·44	1·30	0·116
42·8	1·26	1·48	0·170
58·5	1·24	1·51	0·180
73·3	0·98	1·91	0·281
0·0	1·87	1·00	0·00
100	0·95	1·97	0·294

should be negative at the nickel-rich end of the iron–nickel and cobalt–nickel systems, reaching a maximum of about −500 cal/g atom, but positive at the iron-rich end of the iron–nickel system. There are insufficient data to permit any further discussion of the cobalt–nickel system but the recent measurements by Zellars, Payne, Morris, and Kipp[17] and Speiser *et al.*[18] of activities in the iron–nickel alloys, which give the true excess free energy of mixing in this system, may be compared with that calculated here from the iron–nickel–sulphur system. The binary alloy measurements show that, in fact, the iron–nickel system departs in the negative sense from Raoult's law at *all* compositions, and thus that the theoretical ternary equation is in error at the iron-rich end.

Although our results are by no means sufficient in number to allow discussion of the iron-rich end of this system the dashed line represents a reasonable interpolation. The S-shape of the variation of log γs in this liquid system is also obtained for hydrogen in solution in the solid γ-phase iron–nickel alloys at 1200°C[8] (Fig.8). It can be seen that the differences in affinity between iron and nickel for hydrogen and sulphur are very similar and this suggests that since the pattern of activities in the binary iron–nickel system is probably the same for both solid and liquid alloys near the melting point, then the cause for the S-shaped behaviour is common to both solid and liquid systems. It is thus possible to explain fairly well the departure of the log γs and log γH curves from linearity in the nickel-rich end of these systems from simple theory, but no explanation for the rapid lowering of log γS and log γH brought about by small nickel additions, up to 20 at-% to iron, can be found.



8 *Effect of alloying nickel on the partial molar free energy of solution of hydrogen in solid iron at 1200°C*

It is interesting to note in this connexion that in Chipman and Wriedt's results[12] for dilute solutions of oxygen in liquid iron–nickel alloys a similar lowering of γO, compared with that which would be expected, is to be observed. Until further ternary systems have been investigated it seems inappropriate to speculate on this effect.

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The role of carbon as a deoxidizing agent in the production of vacuum-melted steel

G. H. J. Bennett, B.Sc., Ph.D., H. T. Protheroe, B.Sc., Ph.D., and R. G. Ward, M.A., Ph.D.

SYNOPSIS

A series of steel melts with carbon contents up to 0·85% have been made under vacuum in magnesia refractory crucibles. The influence of the time of vacuum treatment and of agitation, by either rocking the crucible or by argon-lancing, on the degree of deoxidation of the melts by carbon has been examined. A mechanism is proposed for the deoxidation process which indicates that a true dynamic equilibrium condition is eventually attained, giving final oxygen contents corresponding to equilibrium with a carbon monoxide partial pressure of about 2 cm Hg. *Lower oxygen contents are therefore unlikely to be attained in magnesia crucibles.* 1785

INTRODUCTION

AIR-MELTED STEEL is usually deoxidized by additions of ferromanganese, ferrosilicon, titanium, and aluminium, all of which form oxides or complex silicates as deoxidation products. The separation of the resultant slag-forming deoxidation products occurs slowly, if at all, and gives rise to inclusions which often detract from the properties of the finished steel. However, deoxidation by carbon results in the formation of carbon monoxide which, being gaseous, bubbles out of the melt and tends to scourge it of inclusions and dissolved gases. Deoxidation with carbon is thus preferable to the other process in which solid products are formed, if an adequate degree of deoxidation can be attained.

The reaction between carbon and oxygen dissolved in molten iron has been extensively investigated and much of the earlier work has been adequately reviewed by Marshall and Chipman.[1] The slowness and incompleteness of this reaction at atmospheric pressure is well known and is of great technical importance in steel refining and ingot production. The carbon elimination reaction

$$[C]_{Fe}+[O]_{Fe}=CO_{gas} \quad \ldots\ldots(1)$$

is greatly dependent on pressure and this can conveniently be discussed by consideration of the equilibrium constant:

$$K_p=\frac{p_{CO}}{[H_C][H_O]} \quad \ldots\ldots(2)$$

where p_{CO} is the partial pressure of carbon monoxide, and H_C and H_O are the Henrian activities of carbon and oxygen respectively in the molten steel.

The final oxygen content in the steel for a given carbon content is thus proportional to the carbon monoxide partial pressure if equilibrium conditions are obtained. This suggests that if the pressure above the surface of the molten metal is lowered, deoxidation might be effected by carbon alone, e.g. the addition of 3 wt-% of silicon reduces the oxygen content to 0·0015 wt-%, but this oxygen content could also be achieved by 0·2 wt-% of carbon if the partial pressure of carbon monoxide could be reduced to 0·1 atmospheres pressure. This level of deoxidation would be considered acceptable and would, of course, be achieved without formation of any slag-forming deoxidation products.

It is theoretically possible to obtain oxygen contents below 10^{-7} wt-% by processing molten iron and carbon alloys in equilibrium with a carbon monoxide partial pressure of 1 μ, a pressure which is commercially obtainable in vacuum melting and casting units. These extremely low oxygen contents have never been achieved by vacuum-melting techniques, and the failure to achieve this degree of deoxidation has been examined in the present work.

EXPERIMENTAL TECHNIQUE

A series of iron–carbon alloys was prepared using an Efco–Edwards vacuum melting and casting unit. This unit has been adequately described by Barrett and Harper[2] and a photograph showing the inside of the vacuum chamber is shown in Fig.1. In these heats 12 kg (26·5 lb) of iron were deoxidized by small quantities of high purity graphite in the magnesite-lined high-frequency induction furnace at total pressures of less than 2 μ. The crucible was about 4·5 in.

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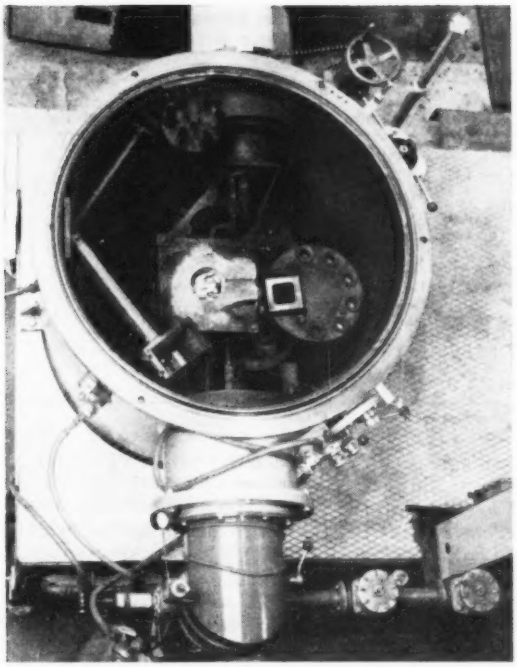


1 *Interior of the Efco–Edwards vacuum melting and casting unit showing the mould turntable designed by the authors*

dia. and the molten metal was about 6 in. deep in all cases.

The materials used were shotblasted melting iron of the composition: 0·04%C, 0·02%Si, 0·04%Mn, 0·065%O, 0·010%N, pure graphite (Morgan's EY9a), sieved and graded magnesia refractory, and commercial cylinder argon.

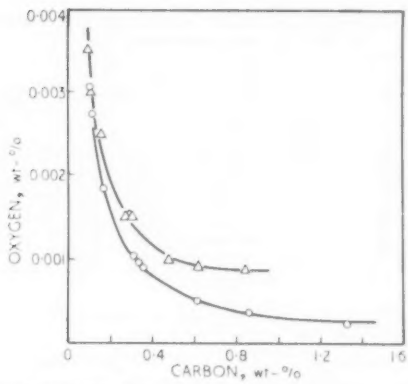
Temperatures were measured by 5%Rh–Pt/20%Rh–Pt dipping thermocouples in molybdenum–alumina cermet sheaths, which could be operated from outside the chamber. Pressures within the apparatus were measured by spiral tube, thermal conductivity, and cold cathode ionization gauges.

Sampling of the heats was facilitated by constructing the mould turntable that is clearly visible in Fig.1. Samples could be poured into any of seven moulds by rotating this turntable: the six smaller moulds are 300 g capacity chill moulds and the square chill mould is capable of receiving the whole of the 12 kg heat.

Preliminary experiments showed that the carbon-boil was always completed within 20–25 min and that the oxygen content of ingots cast under a pressure of 10 cm Hg of argon reached an essentially constant level after being vacuum treated at 1580°C for 25 min. The ingots were allowed to cool before air was admitted to the chamber and they were then removed for analysis.

Samples taken from the top, middle, and bottom of several early ingots showed segregation of oxygen and carbon to be negligible and subsequently mixed drillings from the top, middle, and bottom of each ingot were analysed for carbon. Oxygen determinations were only made on samples taken at about one-third the height of the ingot, at least 0·5 in. beneath the surface.

The first series of ingots was produced from melts



△ concentrations in wt-% by analysis
○ Henrian activities as wt-% by calculation

2 *Relation between oxygen and carbon in series 1 melts, processed for 30 min under 2 μ pressure at 1580°C and cast under argon*

of melting iron and graphite that had been allowed to de-gas for 30 min at 2 μ pressure, while the furnace was rocked to and fro. The evolution of gas from all the melts was accompanied by a visible evaporation of heavy vapour which, when the cooled chamber was opened, gave rise to a black pyrophoric deposit on the chamber walls. Analysis showed this powder to consist principally of manganese and iron oxides. The degassed melts were cast into 28 lb capacity ingot moulds under a pressure of 10 cm Hg of argon. Nine ingots were produced by this technique, covering the range 0·1–0·85%C.

A second series of melts was made from which small samples were vacuum-cast from the melt periodically during processing. The final ingot was cast under 10 cm Hg pressure of argon as in the previous series of melts.

The final series (series 3) was made in which argon bubbles were forced through the molten metal. The argon was injected into the melt through a recrystallized alumina lance immersed 5–5·5 in. below the metal surface for periods of up to 30 min after the melts had been deoxidized by a 20-min carbon-boil carried out at 1580°C under a chamber pressure of 2 μ. The rate of flow was carefully controlled so that excessive turbulence did not occur and a pressure of 4 μ could be maintained in the chamber by the vacuum pumps during the lancing. Finally the ingots were cast under argon.

Steel samples were analysed for carbon by a standard combustion method and all figures presented are the mean of three determinations with an accuracy of ±0·01 wt-%C. The oxygen contents were determined by vacuum fusion using an apparatus similar to that of Cook and Speight;[3] again figures quoted are the mean of at least three determinations, and a reproducibility of ±0·0002 wt-%O was achieved. Practically all the manganese in the charge was lost by evaporation and all ingots contained less than 0·01 wt-%Mn.

EXPERIMENTAL RESULTS

The analyses for carbon and oxygen from ingots produced under typical vacuum melting and casting conditions (series 1) are given in Table I, and the relation-

TABLE I Analyses of series 1 melts; vacuum processed for 30 min and cast under argon

Heat	C%	O%	H_C. [0%.f%]	p_{CO}, cm Hg	H_C	H_O
5	0·10	0·0035	0·000368	11·8	0·105	0·00305
8	0·11	0·0030	0·000351	11·8	0·117	0·00273
11	0·16	0·0025	0·000435	11·8	0·174	0·00184
12	0·27	0·0015	0·000467	11·8	0·311	0·00103
13	0·85	0·0009	0·001201	11·8	1·335	0·00024
14	0·48	0·0010	0·000619	11·8	0·619	0·00052
16	0·30	0·0015	0·000527	11·8	0·351	0·00091
18	0·29	0·0015	0·000509	11·8	0·339	0·00095
55	0·62	0·0009	0·000776	11·8	0·862	0·00037

ship between the carbon and oxygen content of these alloys is plotted in Fig.2.

The analyses of samples taken periodically under vacuum during processing (series 2) are given in Table II, and the results from the argon lancing experiments (series 3) are given in Table III.

DISCUSSION

Deoxidation obtained by rocking melts for 30 min under vacuum and casting under 10 cm Hg pressure of argon (series 1)

It is convenient to assess the efficiency of deoxidation by consideration of the equilibrium carbon monoxide partial pressure, p_{CO}, obtained from equation (2) by use of the appropriate value of K_p; the lower the value of p_{CO} the greater the deoxidation achieved. This procedure avoids the difficulty in comparison of oxygen contents at different carbon contents.

For the calculation of p_{CO} from equation (2) the activity product $[H_C]\,[H_O]$ is required. This may conveniently be expanded:

$$[H_C]\,[H_O]=[\text{wt-\%C}].f^{C}_{C}f^{O}_{C}[\text{wt-\%O}]f^{O}_{O}f^{C}_{O} \quad \ldots\ldots\ldots\ldots(3)$$

where f^{i}_{j} is the Henrian activity coefficient accounting for the influence of i on the element j in solution in molten iron. In the present work the influence of carbon on the activity of carbon has been obtained by extrapolation of gas equilibrium data of Richardson and Dennis[4] as:

$$\log f^{C}_{C}=0{\cdot}23\,[\text{wt-\%C}] \quad \ldots\ldots\ldots\ldots(4)$$

Values for the activity coefficient expressing the influence of oxygen on the activities of carbon and oxygen have been taken from the work of Turkdogan *et al.*[5] and Floridis and Chipman[6] respectively:

$$\log f^{O}_{C}=-0{\cdot}36\,[\text{wt-\%O}] \quad \ldots\ldots\ldots\ldots(5)$$

$$\log f^{O}_{O}=-0{\cdot}20\,[\text{wt-\%O}] \quad \ldots\ldots\ldots\ldots(6)$$

The relation between the final oxygen and carbon contents of the melts of series 1 is shown in Fig.2. If it is assumed that these correspond to an equilibrium condition, the effective value of p_{CO} can be obtained from equation (2) if the activity product $[H_C]\,[H_O]$ is known. This can be obtained by extrapolating a plot of $\log [\text{wt-\%C}]\,f^{C}_{C}f^{O}_{C}.[\text{wt-\%O}]\,f^{O}_{O}$ as a function of carbon content, (Fig.3), to zero carbon content at which the ordinate is equal to $[H_C]\,[H_O]$ (*see* Appendix 2).

Substitution of the extrapolated value of $[H_C]\,[H_O]$ in equation (2) and taking K_p as 500 (*see* Appendix I), gives a carbon monoxide partial pressure of 11·8 cm Hg. This is far in excess of the pressure in the chamber of about 10^{-4} cm Hg which the equilibrium carbon monoxide pressure might be expected to equal, and this apparent anomaly is considered later in a discussion of the mechanism of deoxidation by carbon under vacuum.

TABLE II Analyses of series 2 melts; periodical samples during vacuum processing

Heat	Processing time, min	C%	O%	p_{CO}, cm Hg
80/1	0	0·21	0·0017	10·9
80/2	7	0·20	0·0012	7·5
80/3	25	0·19	0·0007	4·2
80/4	45	0·18	0·0008	4·5
80/5*	85	0·17	0·0007	3·8
81/1	0	0·21	0·0014	9·0
81/2	7	0·20	0·0010	6·2
81/3	10	0·20	0·0009	5·6
81/4	16	0·19	0·0009	5·4
81/5	30	0·18	0·0007	4·0
81/6*	60	0·16	0·0006	3·1

* Analyses on final ingot

TABLE III Analyses of series 3 melts; argon lanced after degassing for 20 min at 1580°C under a pressure of 2μ

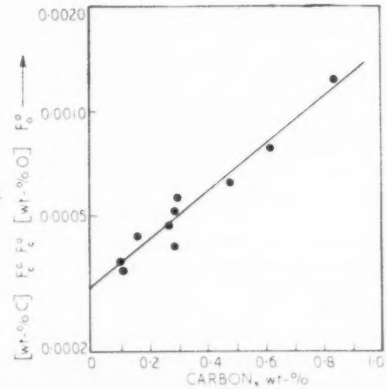
Heat	Lancing time, min	C%	O%	p_{CO}, cm Hg
127/1	0	0·19	0·0014	6·7
151/1	0	0·22	0·0014	9·4
147/1	0	0·21	0·0015	9·7
147/2	2	0·21	0·0012	7·7
121/2	5	0·19	0·0008	4·8
127/2	5	0·19	0·0012	7·1
151/2	5	0·22	0·0006	4·0
121/3	10	0·18	0·0007	4·0
121/4	15	0·18	0·0005	2·9
127/3	15	0·19	0·0005	3·0
127/4	20	0·19	0·0004	2·4
121/7*	20	0·18	0·0004	2·3
194/2	20	0·20	0·0007	4·3
194/3	30	0·19	0·0005	3·0
194/4	35	0·19	0·0005	3·0

* Analyses on final ingot

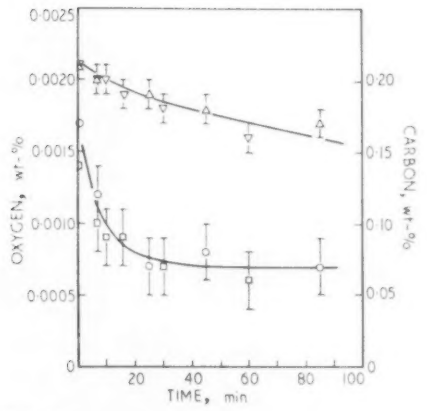
Effect of vigorous agitation, caused by periodic sampling throughout vacuum melting, on deoxidation (series 2)

To allow the kinetics of the carbon–oxygen reaction to be studied, two heats were made (Table II) in which small samples were taken for analysis at regular intervals after meltdown in the period before casting the ingots. The results for the two heats are shown in Fig.4 in which oxygen is seen to reach a constant level (within the accuracy of analysis) after a processing time of about 30 min.

A comparison between the final oxygen content obtained in these heats with that obtained by interpolation of the data from Fig.2 at the same carbon



3 *Variation of log* ($C\%\,f^{C}_{C}f^{O}_{C}.[O\%]\,f^{O}_{O}$) *with carbon content at 1580°C for vacuum melts of series 1*



○ Melt 80—oxygen content
□ Melt 81—oxygen content
△ Melt 80—carbon content
▽ Melt 81—carbon content

4 *Variations in oxygen and carbon content of an initially 0·2%C steel with time during vacuum processing and periodic sampling at 1580°C*

level, shows that continuous sampling has considerably improved the deoxidation of the melt.

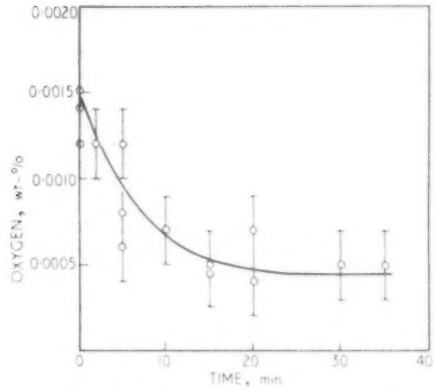
The extent of this improvement is best illustrated by comparing the equilibrium carbon monoxide partial pressures for the final state in the two series of melts; for the first series p_{CO}=11·8 cm Hg while for the second series it is equal to 3·4 cm Hg, indicating an almost fourfold improvement in deoxidation.

It is considered that turbulence caused by frequent sampling has accelerated the approach to equilibrium in these melts and that the apparently constant oxygen content obtained after cessation of the boil in the first series of melts is really an imperceptibly falling content.

Effect of argon lancing under vacuum on deoxidation (series 3)

In order to provide the maximum possible agitation of the bath and to encourage carbon monoxide evolution by providing gas nuclei, argon was blown through the third series of melts. The results of these experiments are given in Table III, and a composite curve showing the fall in oxygen content with lancing time is shown in Fig.5, constructed from samples taken from five heats with initial carbon contents of 0·20±0·02%.

From Fig.5 it appears that these conditions of violent agitation will lower the oxygen content to about 0·0005%, which is slightly, although hardly significantly, less than the level of 0·0007% obtained by vigorous agitation in series 2 melts. This level of 0·0005%O probably represents the minimum deoxidation by carbon which can be obtained under vacuum-melting conditions, although this could not be verified since attempts to prolong argon blowing beyond 30 min proved unsuccessful owing to mechanical failure of the recrystallized alumina lance tip. Alumina/molybdenum cermet lances and bottom blowing through porous refractory plugs have enabled blowing to be done for longer times but in both cases the technique has resulted in severe contamination of the melts by solid oxide inclusions producing an increase



5 *Variation in oxygen content of 0·2%C steels with time of argon lancing at 1580°C*

in the total oxygen obtained by vacuum fusion analysis.

The extent to which agitation by argon lancing improves the deoxidation of the melts is again best illustrated by comparing values of the equilibrium carbon monoxide partial pressures. For this series of melts p_{CO}=2·3 cm Hg, is slightly lower than the value of 3·4 cm Hg obtained for the second series and represents a fivefold improvement on the deoxidation achieved in the first series (p_{CO}=11·8 cm Hg).

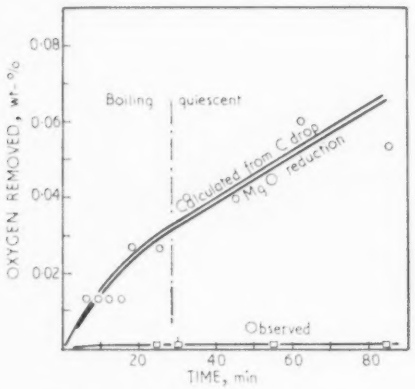
A proposed mechanism of the deoxidation of vacuum melts by carbon

An understanding of the mechanism by which the final oxygen contents were attained in the melts of series 2 and 3 can be obtained by considering the overall flow of oxygen in any one melt. This can be done by comparing the changes in the carbon and oxygen contents during a melt: e.g. the data from the course of two melts initially containing 0·2%C, given in Fig.4, show that the carbon lost is far in excess of that necessary to account for the observed oxygen drop, i.e. they are not related by equation (1) according to which the weight percentage of carbon removed should be equal to $\frac{12}{16}$ of the weight percentage loss of oxygen.

The total carbon removed must have been evolved as carbon monoxide and is therefore equivalent to the total oxygen removed from the melt. This total oxygen must be made up of the oxygen drop observed together with oxygen derived from the refractory lining This oxygen derived from the lining, $[O]^{MgO}$, can therefore be calculated as the difference between the oxygen equivalent to the carbon removed during vacuum processing, $[O]^{C}$, and the observed drop in the oxygen content of the heat, $[O]_{Fe}$; this is shown in Fig.6.

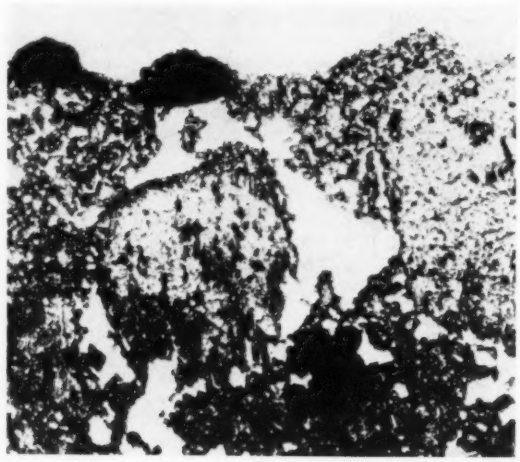
From Fig.6 it is evident that although the oxygen content of the melt becomes substantially constant after 20–30 min, oxygen is still being removed from the system at a considerable rate. The particular value of the final 'equilibrium' oxygen content of the melt must be fixed by the mechanism of carbon monoxide evolution, and this is now considered.

Since the homogeneous nucleation of carbon monoxide bubbles within the melt is improbable[7] the only possible mechanisms of carbon monoxide removal are



○ oxygen calculated from carbon drop
□ observed oxygen removal

6 *Comparison between removal of oxygen as calculated from the carbon drop and that determined experimentally, expressed as a function of processing time, for a 0·2%C steel*



7 *Section through a magnesia furnace hearth showing probable gas nucleation site. Metal appears black*
×30 transmitted light

bubble nucleation at the metal/refractory interface and desorption from the metal surface. As bubble evolution, i.e. a boil, is only observed during the first 20–30 min of the process after which the surface remains undisturbed, it is evident that the carbon removed during the latter period corresponding to the constant rate position of curve $[O]^C$ in Fig.6, is lost by desorption of carbon monoxide from the surface. Both processes are no doubt operative during the boil.

The removal of oxygen, $[O]^C$ of Fig.6, may thus be considered as the sum of two processes:

(i) *Carbon monoxide bubble evolution*

This is initially rapid but dies away as the oxygen content of the melt is lowered. The cause of the decay in bubble evolution is evident from consideration of the conditions for the operation of a capillary crevice in the refractory as a nucleation site; for the site to be active the internal pressure in a hemispherical bubble of radius equal to the capillary must be greater than the sum of the pressures limiting bubble growth:[8]

$$p_{CO} \geq p_{Fe} + \frac{2T}{r} \quad \ldots\ldots(7)$$

where T is the surface tension of the metal, p_{Fe} is the hydrostatic pressure on the bubble, and r is the radius of the capillary crevice.

Initially, when the oxygen in the metal is high p_{CO}, which is related to the activity of oxygen in the melt by equation (2), is also high, and equation (7) is satisfied by a wide range of nucleation crevices. The lowering of oxygen in the melt progressively lowers p_{CO} and the minimum active crevice radius increases until eventually metal penetration of the crevices occurs and the crevices cease to be active.

The critical value of p_{CO} at which bubble nucleation ceases is 12 cm Hg, obtained by substitution of the experimental carbon and oxygen contents at the end of the boil into equation (2). From observations on the carbon boil under atmospheric pressures[9] it is known that bubble nucleation occurs predominantly on the crucible bottom and not on the walls, so that p_{Fe} may be taken as equal to the total head of metal in the crucible of 8·1 cm Hg. Substituting these values of p_{CO} and p_{Fe} in equation (7) gives a crevice radius of 0·05 cm; examination of sections of the lining from the crucible bottom reveals many crevices a little smaller than this, a typical example being shown in Fig.7, and it seems reasonable that these are the active sites during the boil.

(ii) *Surface desorption of carbon monoxide*

The rate of chemical combination of carbon and oxygen is known to be high, and it is probable that surface desorption will be diffusion limited. Under conditions where diffusion is rate-controlling the supply to the interface of the reactant that is least available, oxygen in this case, is rate-limiting. The rate of reaction can be shown from Fick's First Law to be proportional to the area of the interface and the concentration of oxygen in the bulk of the metal.[10] Although the value of the interface area is slightly larger during the boil than when the bath is quiescent, it is roughly constant and the rate is proportional to the oxygen content, i.e. it is initially rapid but settles down to a steady value as the boil subsides.

The removal of oxygen by mechanisms (i) and (ii) is counteracted by an uptake of oxygen from the refractory. The rate of solution of MgO will probably be determined by the rate of removal of magnesium and oxygen from the refractory/metal interface; as the solubility of magnesium in steel is very limited the rate may well be determined by the rate of removal of magnesium from the melt. Initially this will be facilitated by the boil, but loss from the surface will become constant (by diffusion arguments similar to that previously used for oxygen supply to the metal surface) and the rate of supply of oxygen from the refractory $\left(\frac{dO}{dt}\right)^{MgO}$ will therefore also become constant. In the quiescent period it is not considered that direct reduction of MgO by carbon occurs:

$$\langle MgO \rangle + [C]_{Fe} = Mg + CO_{gas} \quad \ldots\ldots(8)$$

as this would result in an observable boil, although this may occur during the initial boil period; even

during the boil the contribution from reaction (8) is probably limited as this can only occur where the three phases magnesia, steel, and carbon monoxide are in contact along a line.

Summing these three processes, bubble evolution of carbon monoxide, surface desorption of carbon monoxide, and uptake of oxygen from the refractory, indicates that an equilibrium condition will be set up when the overall rate of removal of oxygen from the melt $\left(\frac{dO}{dt}\right)^{C}$ equals the rate of solution of oxygen from the refractory $\left(\frac{dO}{dt}\right)^{MgO}$. The rate of removal of oxygen from the melt decreases with decreasing oxygen content (the sum of processes (i) and (ii)) and the rate of solution of the refractory $\left(\frac{dO}{dt}\right)^{MgO}$ may either be constant or increasing with decreasing oxygen in the melt. The final oxygen content is thus dependent on the rate of oxygen pickup from the refractory $\left(\frac{dO}{dt}\right)^{MgO}$.

If, as discussed above, this depends on the rate of loss of magnesium from the metal surface then it will not be affected by crucible geometry, e.g. increasing the area of the free metal surface will increase both the rate of loss of magnesium and of carbon monoxide to the same extent, and the equilibrium oxygen content will be unchanged. This also accounts for the failure of argon blowing to reduce the oxygen in the metal to a level in equilibrium with carbon monoxide at a pressure equal to that within the tank of about 4 μ, i.e. to about 10^{-7}%O, which might be expected if the problem were solely a matter of providing gas nuclei. The increased surface area produced by argon lancing must increase both the rate of loss of magnesium and that of carbon monoxide: the equilibrium oxygen content therefore remains unchanged.

CONCLUSIONS

In the absence of any vigorous agitation a pseudo-equilibrium is set up after the boil has ceased, and the oxygen content becomes practically constant. The carbon and oxygen contents then correspond to an equilibrium partial pressure of carbon monoxide of 11·8 cm Hg. The pseudo-equilibrium data lead to a variation of the activity coefficient of oxygen with carbon content according to:

$$\log f^{C}_{O} = -0{\cdot}67\ [\text{wt-}\%C]$$

Violent agitation of the melts by vigorous slopping of the melts or by argon lancing considerably lowers the oxygen content, and the effective carbon monoxide equilibrium pressure is lowered to about 2 cm Hg, corresponding to a carbon–oxygen activity product $[H_C]\,[H_O]$ of 0·00005. It is considered that this is a true equilibrium state for vacuum steel melts in MgO crucibles; this fixes the lowest oxygen content and lower oxygen contents are therefore not obtainable.

ACKNOWLEDGMENTS

The authors are indebted to Professor A. G. Quarrell for his interest and encouragement in this work. One of us (G.H.J.B.) gratefully acknowledges the financial support from the University of Sheffield made available through the Tube Investments Metallurgical Research Fund.

APPENDIX I

The value of the equilibrium constant K_p

In the present work a value is required for the equilibrium constant K_p (equation 2) of the reaction between carbon and oxygen in liquid iron (equation 1) at the processing temperature of 1580°C.

Marshall and Chipman's experimental data[1] has been recently examined by Vallet[11] at 1540°C and a value of 469 ± 41 for K_p was obtained which may be compared with their own value of 512. Stark[12] has also re-examined Marshall and Chipman's data and gives a value of 504. Vallet[13] has calculated the value as 455 at 1600°C from the work of Larsen.[14]

From indirect experimental data on the carbon–oxygen reaction Turkdogan *et al.*[15] have proposed a relation that gives a value of 502 for K_p at 1580°C. The present authors have re-evaluated the original data, from which Turkdogan *et al.* derived their relationship, and obtained a slightly modified expression:

$$\log K_p = -\frac{1045}{T} + 2{\cdot}131 \quad \ldots\ldots(9)$$

giving K_p equal to 495 at 1580°C with a probable accuracy of ± 10%.

In view of the divergence among the values proposed for K_p, a round figure of 500 has been adopted in the present work.

APPENDIX II

Calculation of the equilibrium carbon monoxide partial pressure and the influence of carbon on the activity of oxygen from the measured carbon and oxygen contents of series 1 melts

If the value of K_p is known (Appendix 1) the value of p_{CO} can clearly be obtained from equation (2) if the Henrian activity product $[H_C]\,[H_O]$ is known. As indicated in the first part of the discussion, the activity product may be expanded to

$$[H_C]\,[H_O] = [\text{wt-}\%C] f^{C}_{C} f^{O}_{C} \cdot [\text{wt-}\%O] f^{O}_{O} f^{C}_{O} \quad \ldots\ldots(3)$$

in which only f^{C}_{O} is inadequately known, but may be expected to obey a logarithmic relation similar to equations (4), (5), or (6), i.e.

$$\log f^{C}_{O} = \text{constant} \cdot [\text{wt-}\%C] \quad \ldots\ldots(10)$$

Combination of equations (3) and (10) gives:

$$\log\{[\text{wt-}\%C] f^{C}_{C} f^{O}_{C} \cdot [\text{wt-}\%O] f^{O}_{O}\} = \log [H_C]\,[H_O] - \text{constant}\,[\text{wt-}\%C] \quad \ldots\ldots(11)$$

The left hand side is known for a series of carbon and oxygen values and this is plotted logarithmically as a function of [wt-%C] in Fig.2. Equation (11) shows that the activity product $[H_C]\,[H_O]$ is given by the intercept at zero carbon content and that the constant is equal to the slope of the graph.

From Fig.2 the activity product for series 1 melts is

$$[H_C]\,[H_O] = 0{\cdot}00031 \quad \ldots\ldots(12)$$

which, on substitution in equation (2) taking $K_p = 500$, gives $p_{CO} = 11{\cdot}8$ cm Hg.

Also from the slope of the graph of Fig.2 the general expression for the activity coefficient of oxygen in the presence of carbon is

$$\log f^{C}_{O} = -0{\cdot}67\ [\text{wt-}\%C] \quad \ldots\ldots(13)$$

Turkdogan *et al.*[15] give a value $-0{\cdot}49 \pm 0{\cdot}12$ for this constant; Chipman[16] gives the value $-0{\cdot}41$ as an approximation only, based upon his earlier work with Marshall.[1]

From the accuracy of the data used it is estimated that the value of $-0{\cdot}67$ presented here is correct to about $\pm 0{\cdot}17$; this value is in general agreement with those proposed by other workers and although it has been used throughout the calculations it is not proposed as a new value in view of the small amount of data upon which it is based, and because of the absence of a complete state of thermodynamic equilibrium in the melts at the time when the analyses were made.

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A magnetite seam at the scale/metal interface on mild steel

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SYNOPSIS

The presence of magnetite at the scale/metal interface has been reported elsewhere[1] in adherent scales. Similar structures are illustrated and the possible mechanisms of formation of a higher oxide in an area of relatively low oxygen concentration are considered. The magnetite seam may be relevant to the behaviour of the oxide layer in pickling and mechanical descaling. 1787

INTRODUCTION

THE SCALE ON STEEL oxidized in air consists of three layers: ferric oxide at the outside, magnetite further in, and wüstite, usually by far the thickest layer, next to the metal substrate. The oxygen content of these phases decreases progressively and their iron content increases; their relative positions in the scale are consistent with their constitutions, the phase richest in oxygen being at the surface, the oxide with the highest iron content close to the metal. Within the wüstite layer itself there is a linear concentration gradient[2,3] from iron-rich wüstite at the scale/metal interface, to oxygen-rich wüstite at the phase boundary where the wüstite is in equilibrium with magnetite.

The classical three-layer structure appears only in scales that adhere to the surface of the steel. Scale on hot-worked products frequently flakes locally and cracks along the interface can also be found on specimens scaled in laboratory treatments. Separation of the scale from the substrate does not upset the three-layer structure unless the atmosphere can penetrate into the crack; all that happens is a change in the relative proportions of the phases and saturation of the wüstite layer with oxygen.[2–4] In practice, however, cracking of the scale often allows oxygen to penetrate into the gap between the metal substrate and the scale. In this way the inner layer of wüstite is enriched in oxygen and the gap surfaces may even be oxidized to magnetite; this has been observed frequently and is illustrated in Fig.1. Magnetite in this location is still consistent with the oxygen distribution.

However, a narrow layer or seam of magnetite has been observed at the oxide/metal interface of adherent scales. In an examination of the scale on hot-rolled strip, Garber[1] discovered what he calls a 'sandwich' structure, in which the wüstite is bordered by magnetite on the inside as well as the outside of the scale. Examination of the scale on hot-rolled rods has confirmed the presence of a thin magnetite seam at some points of the scale/metal interface and the present paper is concerned with a detailed examination of some features of the scale structure associated with this phenomenon. Some speculation on its origin is also included.

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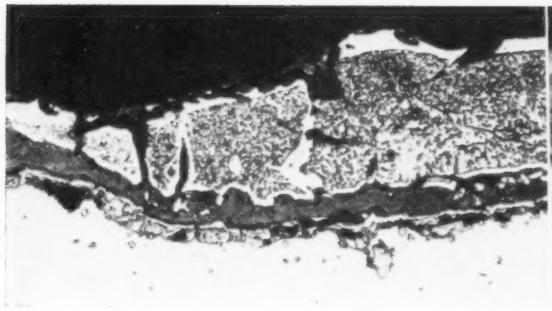
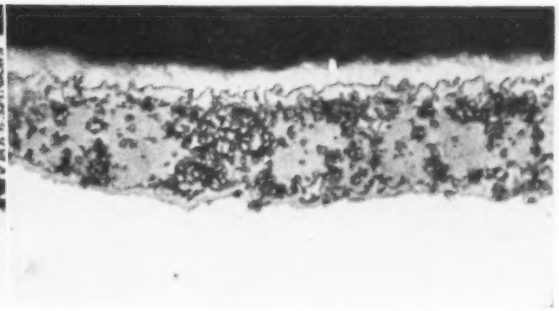
MICROSTRUCTURES OF SCALES

The magnetite seam at the scale/metal interface is not an obvious feature of the microstructure. It is very thin and can only be detected at fairly high magnifications on well polished specimens.

Typical scale structures are shown in Figs.2 and 3. The scale consists mainly of wüstite with a thin outer layer of magnetite. Magnetite particles are also present in the wüstite phase; the coarser ones have the characteristic shape associated with pro-eutectoid precipitation above 570°C,[5] the finer ones may have a similar origin or may have been formed in the first stages of the breakdown of wüstite below 480°C.[6–8] The proportion of precipitated magnetite is greatest at the outside and diminishes appreciably towards the middle of the wüstite layer. At the inside of this layer,



1 *Oxidation of cracks and fissures by atmosphere penetration. Scale on hot-rolled billet* ×500

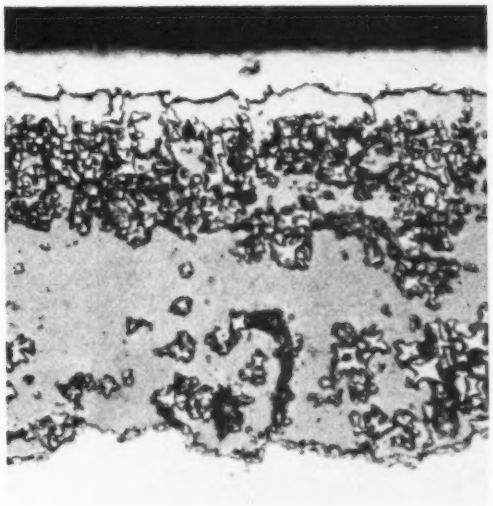


2 *Scattered magnetite particles in the wüstite layer and magnetite seam at the interface. Scale on hot-rolled rod* ×1000

close to the metal surface, the amount of magnetite increases again and Fig.2 shows a coherent seam of magnetite. A similar micrograph has been published without comment by Dahl and Lueg.[9] In thicker scales the precipitated magnetite particles are coarser, as in Fig.3 where a row of magnetite particles can be clearly distinguished at the interface. Figure 4 shows a similar seam in a scale free from discrete particles of precipitated magnetite. A particularly well-developed seam is shown in Fig.5; it is quite continuous but has a heavily serrated edge and some rounded pores can also be observed.

The direct attachment of the magnetite to the metal substrate is proved by electron micrographs of the scale/metal interface (Fig.6). The magnetite seam has a serrated edge, suggesting that it consists of a continuous row of crystals growing from the interface.

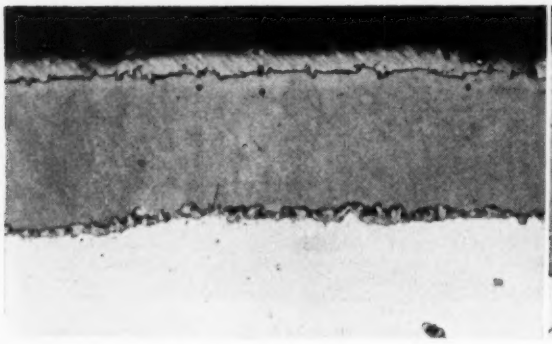
A particularly instructive survey of scale structures is presented in Fig.7. This is a composite photograph showing a short stretch, extending over 0·037 in., of the scale on a hot-rolled rod. The dominant feature is a large gap, about 0·014 in. long, in the middle of the photograph; on both sides of the continuous gap there are elongated cavities. Oxygen has penetrated into the gap and has greatly increased the proportion of ferric oxide and magnetite in the scale; the wider magnetite layer extends much further laterally than the gap itself. Between the gap and the metal there is an adherent scale deposit consisting of a wide magnetite layer, a slightly narrower wüstite layer, and a magnetite seam at the interface (*cf.* Fig.7*a*), which extends beyond the dimensions of the existing gap about as far as the full width of enhanced oxidation. Some distance away, at both sides of the gap, the scale structure is consistent with oxidation as an adherent layer, but has parted from the substrate; the wüstite near the zone of separation is not oxidized, so that the scale has probably cracked away from the metal during cooling of the rod or preparation of the specimen. The mechanical cracks at both sides penetrate slightly only into the central zone and overlap a little with the magnetite seam (Fig.7*b*). This may suggest that mechanical cracking is easier in the absence of a magnetite seam, but the observation is open to another interpretation which will be discussed later.



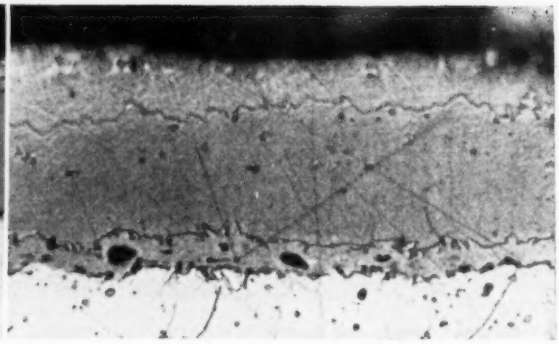
3 *Coherent film of fine magnetite particles at the interface. Scale on hot-rolled rod* ×1000

The fact that the thickening of the magnetite layer, which is undoubtedly caused by separation of the scale from the substrate during oxidation, extends a considerable distance beyond the ends of the gap suggests that the latter was originally wider and has shrunk inwards during oxidation. Presumably there is an analogous lateral shrinkage of the thick magnetite layer, but this evidently lags behind the healing of the gap. Some distance beyond the ends of the gap, where the thick magnetite layer begins to taper off, a string of small particles of magnetite runs obliquely from the primary magnetite layer to the metal surface (Figs.7*b* and *c*). Apparently this is a characteristic feature of long gaps in the body of the scale; other examples have been found on the same specimen. Figure 7 gives the impression that before cracking the magnetite seam was continuous up to the point where it is joined by the comet's tail of magnetite particles; beyond that point there were some discrete magnetite particles at the interface, which gradually petered out further away from the gap. It seems possible that the points where the magnetite stringers join the interface mark the extent of the original gap; these points are indicated by arrows in the composite photograph, Fig.7.

Near the end of such a gap the magnetite surrounding it may be separated from the outer layer of magnetite by wüstite. Figure 8 shows the magnetite border extending a considerable way beyond the gap in the form of a thick slab before it thins out to a comet's tail of separate particles.



4 *Magnetite seam without scattered particles. Scale on hot-rolled rod* ×1000



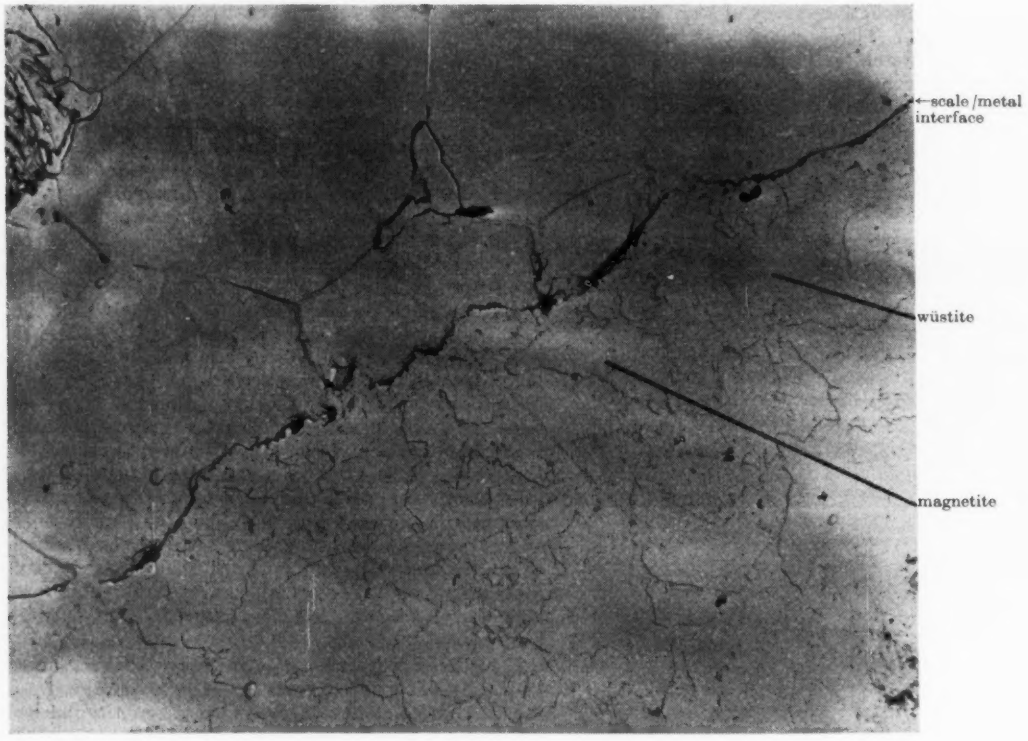
5 *Thick magnetite seam, showing pores. Scale on hot-rolled rod* ×1000

DISCUSSION

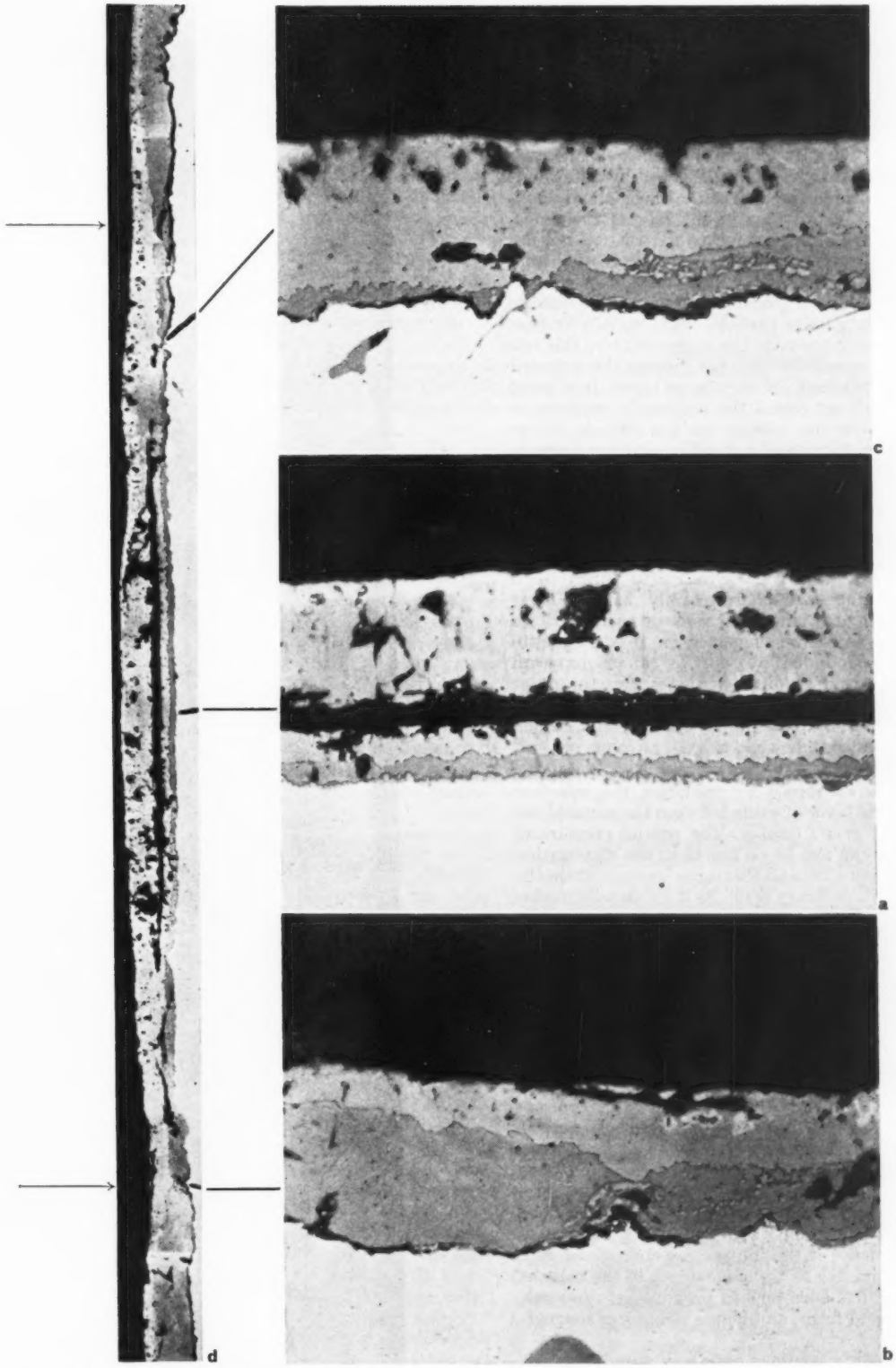
Migration and healing of the gap

The extended gap in the scale shown in Fig.7 has apparently originated from a longer gap presumably formed at the scale/metal interface by the separation of the oxide from the substrate.[4] In the course of subsequent scale growth the gap has contracted laterally and become separated from the interface by an adherent oxide layer. Lateral contraction implies that the gap is healed or filled up by oxide growing inward from the ends. While the gap is located at the interface, its end is the only point where both iron and oxygen are conveniently available for oxide formation, and even when there is oxide beneath the gap, closing up and healing is most likely to proceed from the ends inward. It is in the magnetite border surrounding the gap that this healing process must take place, and magnetite remains in the scale to mark the site of the original gap; the micrographs show that unhealed cavities are also left behind.

While the magnetite border may be left behind for a short time after the ends of the gap have healed, it is difficult to account for its persistence as a discrete phase embedded in wüstite. If the gap heals by the oxide closing in and filling the cavity from the ends, then the extent of the magnetite trace is a measure of



6 *Magnetite at interface and in the scale on hot-rolled rod. Formvar–carbon replica* ×2300



(a) ×1000 (b) ×1000 (c) ×1000 (d) ×260

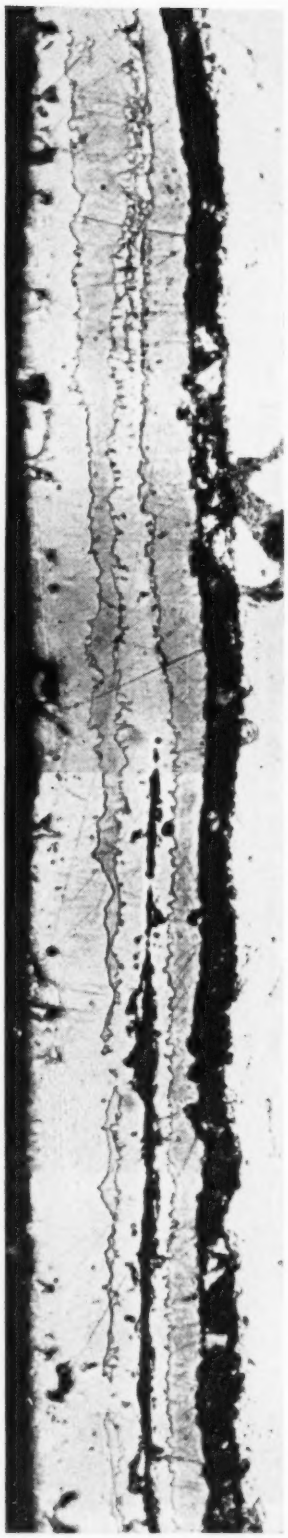
7 *Extended gap in scale of hot-rolled rod*

the persistence of the magnetite under these circumstances; this is shown with particular emphasis in Fig.8, illustrating one end of a gap with a very extensive magnetite trace. In principle, magnetite particles should dissolve in the surrounding wüstite just as carbides are dissolved by austenite above the transformation temperature. There may be profound differences in the rate of solution, however, because the component that has to be dispersed by diffusion is relatively mobile in the case of the carbide and virtually incapable of diffusion in the case of the oxide. Thus the magnetite transforms to wüstite not by dispersion of oxygen ions but by dilution with iron. If the rate of reaction at the interface is slow no substantial iron diffusion gradient is set up in the wüstite towards the magnetite particles and iron can by-pass them on its way towards the outer surface; this implies that the magnetite does not disturb this outward diffusion by blocking off very large areas. Iron must also be able to get round the magnetite particles or veins and reach the wüstite on the outside of the healed-up gap, to replace iron diffusing from there to the outer surface; otherwise this wüstite is oxidized by the loss of iron, as can be seen in the progressive thinning of the intermediate wüstite in Fig.8.

This explanation of the persistence of primary magnetite in the wüstite depends on the assumption that iron crosses the wüstite/magnetite interface to reduce the magnetite more readily at the layer boundary than at interspersed veins or particles. Two possible reasons can be suggested for this: magnetite completely surrounded by wüstite cannot have an iron concentration gradient across it like the outer scale layer, and the transformation of magnetite to wüstite involves an expansion of about 2·66%, which would impose considerable triaxial strains on embedded particles.

As metal is consumed by oxidation the interface recedes and the layer of oxide between the gap and the metal surface grows thicker. The partial pressure of oxygen in the gap can be no less than the dissociation pressure of magnetite and this inner layer grows in the same way as an ordinary scale. As it thickens it pushes the gap outwards, and this migration is encouraged by dissociation of oxide at the outer wall of the gap to maintain the partial pressure of oxygen.[10] The magnetite particles left by the healing of the gap at the ends, however, are embedded in a thicker scale layer and may be regarded as inert markers. It has been shown that the gradual inward creeping of the scale, which normally maintains the contact between the scale and the receding interface,[4] is capable of moving inert markers inwards.[4, 11] The outermost magnetite particles, which formed when the distance between the gap and the interface was relatively small, have been exposed to this action for the longest time and have kept up with the inward recession of the metal surface. Particles formed later and correspondingly further out in the scale will also have moved inwards but not so far. Thus the trace of the contracting ends of the gap, instead of remaining at the same depth in the scale as the gap itself, has been pushed progressively towards the interface and forms an oblique stringer of magnetite particles.

The origin of the complex scale structure in Fig.7 is briefly summarized in a series of sketches in Fig.9. The first crack at the interface is shown at *a*, separating the



× 633

8 *Healing of gap in scale of hot-rolled rod*

wüstite from the metal. Figure 9*b* shows the effect of the gap in blocking outward diffusion of iron, slowing down oxidation, and allowing a thicker magnetite layer to form: the atmosphere has just penetrated into the gap and a narrow border of magnetite has formed. At *c* the oxygen in the gap has oxidized the metal beneath, forming an adherent two-layer scale. The magnetite border round the gap has merged with the outer magnetite layer. The gap has contracted laterally and the healing traces have been pushed towards the interface. Figure 9*d* shows the position reached in Fig.7, with a comet's tail of magnetite particles running obliquely from the end of the gap to the metal surface. Accelerated oxidation across the thin scale under the gap has compensated for the earlier delay in oxidation illustrated at *b*.

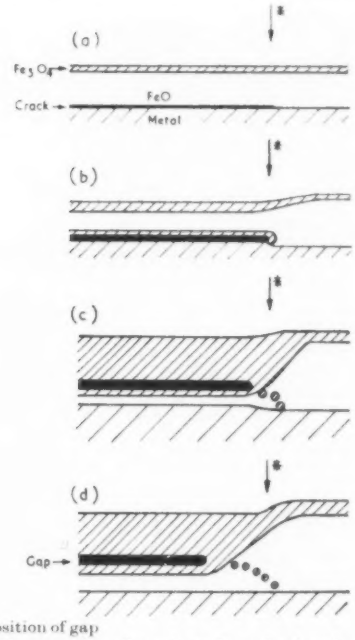
The sketches do not show the magnetite seam at the interface because this structural feature also occurs in other scales, where there is no gap. Its origin merits separate consideration.

Origin of the magnetite seam

In the scale on commercially produced steels, magnetite is formed by the oxidation of wüstite or by its decomposition on cooling. The magnetite in the interface seam must have formed as a result of oxygen penetration under the scale or of localized nucleation of the breakdown of wüstite. One possible explanation is that it forms as a border to a gap containing oxygen and that contact with the metal surface is re-established later by some healing process, but such a mechanism cannot explain the persistence of continuous magnetite seams and it would appear more profitable to consider the possible formation of a magnetite seam at the interface without local oxygen enrichment.

According to the iron–oxygen equilibrium diagram, wüstite undergoes eutectoid breakdown into magnetite and iron at 570°C. This reaction can be undercooled quite easily and wüstite can be preserved at room temperature; at intermediate cooling rates, partial breakdown may be observed. The detailed mechanism of the dissociation of wüstite has been studied by cooling crucible-melted wüstite to room temperature and reheating it to various temperatures below 570°C,[7] as well as by rapid cooling to such intermediate temperatures followed by isothermal treatment;[6,12] understanding of this mechanism can be used to interpret the structure and constitution of scale on commercial steel products.[8,9] The breakdown of wüstite proceeds most rapidly around 480°C by whatever route this temperature range is reached, e.g. by continuous cooling, isothermal 'quenching', or reheating (tempering); the equilibrium products, magnetite and iron, are formed. In the temperature range between 570° and 480°C., iron is precipitated first and there is a corresponding increase in the oxygen content of the remaining wüstite, which ultimately breaks down into magnetite and iron. Below 480°C magnetite is precipitated first and the remaining wüstite is enriched in iron until decomposition is completed with the separation of iron, together with more magnetite.

Examination of the scale on commercial plate,[9] hot-rolled rod,[8] and strip,[1] has revealed the presence of magnetite and iron-rich wüstite, but no iron has been found in any of the oxide layers. Evidently the cooling rates employed in the manufacture of these products



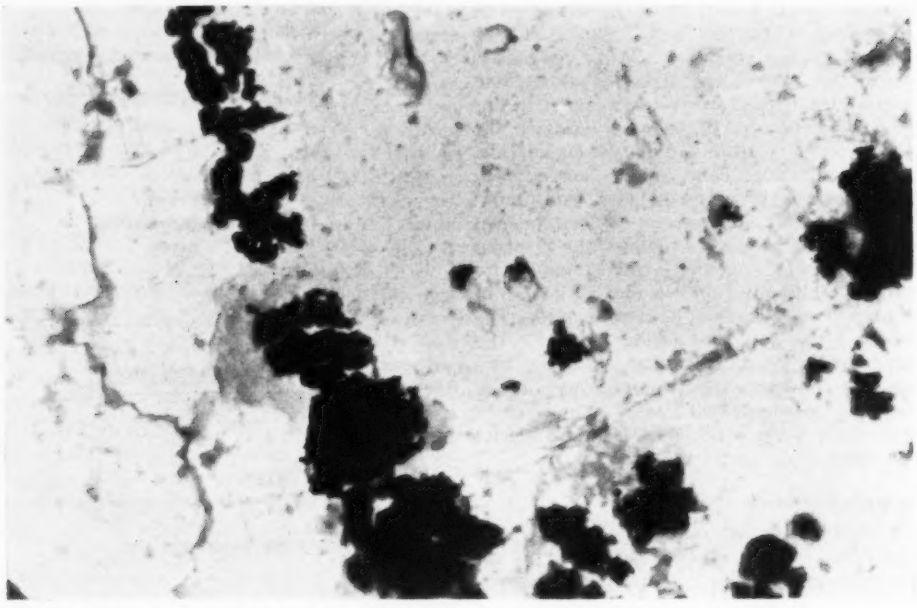
*Initial position of gap

9 *Lateral contraction of gap in scale and migration of magnetite trace*

are fast enough to suppress wüstite breakdown at and above 480°C, but allow it to decompose partially at a lower temperature. Magnetite may therefore be embedded in the wüstite layer, not only as a result of pro-eutectoid precipitation from oxygen-rich wüstite,[5] but also as a product of the partial decomposition of wüstite.

There is some evidence[13] that iron may be precipitated without being detected in the microstructure of the scale. Over most of the thickness of an adherent wüstite layer the iron deficiency increases linearly, but in the immediate vicinity of the metal itself there is a slight decrease, with a minimum at a distance of about 10 μ from the interface.[2,3] This is attributed to precipitation of iron from the wüstite in this very thin inner layer; the iron is believed to migrate back to the metal surface. Deposition of iron at the interface was also observed in scale on Armco iron transformed isothermally at 450°C.[6]

One way of forming a structure with a magnetite seam between iron and wüstite would be by decomposition of the wüstite below 480°C, provided it can be shown that the precipitation of magnetite is likely to be initiated at the interface. From the point of view of wüstite composition, preferential initiation of decomposition in the iron-rich area near the metal surface seems highly improbable because the bulk of the experimental evidence indicates that iron-rich wüstite is more stable than oxygen-rich.[14–19] In a wüstite layer with a linear concentration gradient, decomposition should therefore start at the outside and move inward gradually. Even the local decrease in iron content at the metal surface, due to precipitation of iron at the interface, would not seriously affect this process, because the highest iron vacancy concentration recorded in the wüstite close to the metal surface[2,14] is only equivalent to the eutectoid composition of the wüstite phase. Admittedly the effect of iron



Coarse magnetite particles, possibly originating in seam

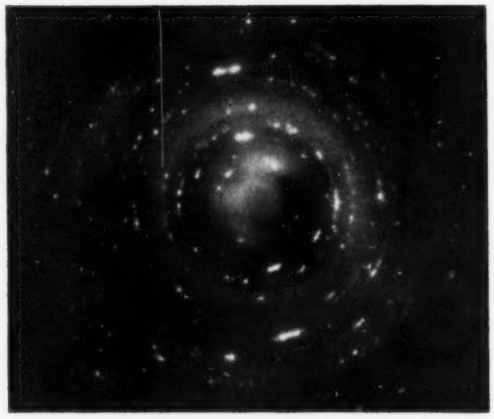
10 *Carbon extraction replica of scale on hot-rolled rod with magnetite seam, showing absence of fine magnetite precipitate* × 17 600

concentration on the stability of wüstite has not been studied over the whole range of composition, and there is an indication that the relation is not linear at the iron-rich end: thin wüstite films saturated with iron at 700°C decomposed a little more readily than others saturated at 600°C and containing slightly less iron, but reaction rates and stabilities of thin films differ profoundly from those of scales or bulk oxides.[20, 21]

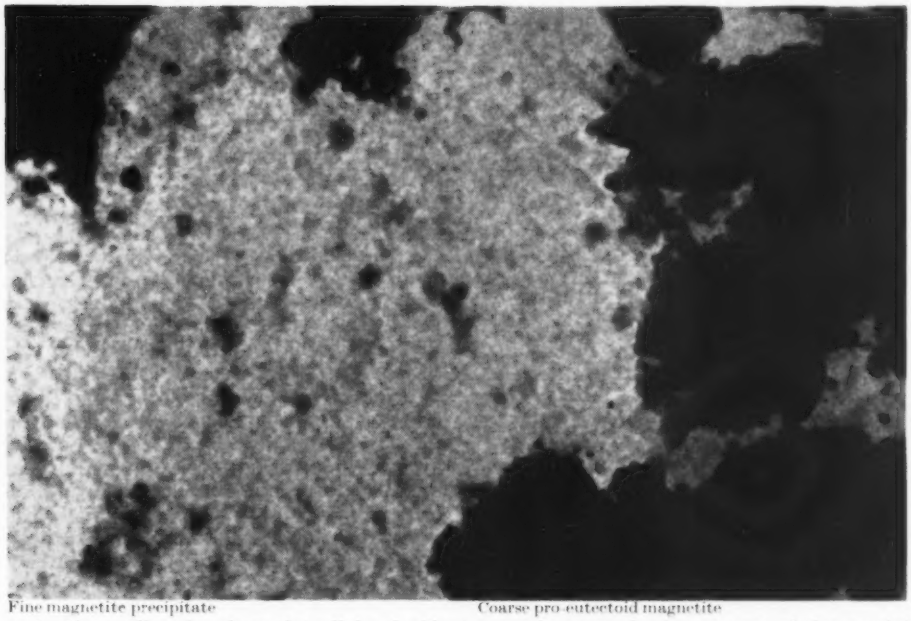
Although wüstite saturated with oxygen transforms most readily and decomposition would therefore be expected to start at the outside of the wüstite layer, the zone close to the scale/metal interface is known to be enriched in a variety of other elements present in the steel;[22, 23] these elements may lower the stability of the wüstite so that it transforms more readily near the interface. The effect of composition on wüstite stability requires further study. Meanwhile it may be useful to consider what other characteristics of the interface might have a nucleating effect strong enough to overcome the unfavourable influence of iron concentration.

There is some experimental support for a nucleation mechanism in a comparison of carbon extraction replicas of the scale close to the metal surface on two samples of hot-rolled rod, one with a magnetite seam at the interface, the other without. The electron micrographs are shown in Figs.10 and 12, the corresponding diffraction patterns in Figs.11 and 13. Large particles of magnetite were extracted from the sample with a magnetite seam (Fig.10) and the diffraction pattern (Fig.11) is very spotty, indicating coarse particle size. The specimen without the magnetite seam yielded a large number of extremely fine magnetite particles in addition to coarse, pro-eutectoid ones (Fig.12); the diffraction pattern (Fig.13) shows both sharp spots for the large particles and diffuse rings corresponding to the fine background material. Under roughly similar cooling conditions the decomposition of wüstite has led to very fine, scattered, precipitation of magnetite in one specimen, and to the formation of fairly coarse particles at the scale/metal interface in the other; this clearly points to the presence of nuclei for magnetite deposition in the specimen forming the seam.

Three possible mechanisms of nucleation of wüstite decomposition at the metal interface will be considered. The first possibility is that residual magnetite from a gap that has been healed may nucleate the decomposition of wüstite into magnetite and iron-rich wüstite. The same reaction is known to occur at the magnetite/wüstite boundary where it is favoured by the wüstite composition; the presence of magnetite may provide an added stimulus and this may be strong enough to nucleate the reaction near the metal, where the composition is less favourable, just as the addition of



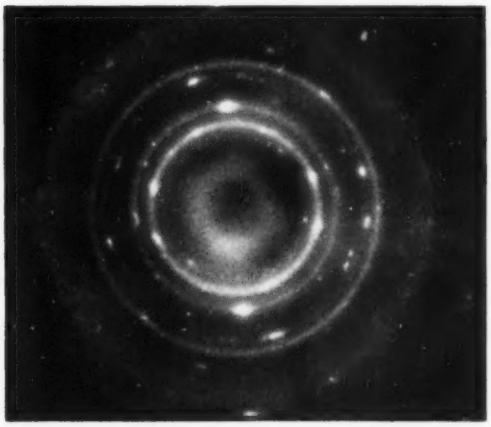
11 *Electron diffraction pattern of scale shown in Fig.10; sharp spots indicate that only coarse particles are present*



12 *Carbon extraction replica of scale on hot-rolled rod without magnetite seam, showing presence of fine precipitate. As in Figs.10 and 11* ×39200

a seed crystal will nucleate precipitation from a saturated solution.

The second factor that may favour the initiation of wüstite decomposition at the surface of the metal is the compressive stress in the wüstite at the metal/oxide interface.[24] Continuous heating of homogeneous wüstite samples in a dilatometer[7] showed that decomposition starts around 300-310 C with a contraction associated with the precipitation of magnetite; at slightly higher temperatures, near 450 C, there is a pronounced expansion due to the further breakdown of wüstite and the formation of iron particles. The contraction resulting from the precipitation of magnetite would tend to relieve compressive stresses in the oxide layer; it follows, with a polite nod to Le Chatelier's principle, that the internal stress favours the precipitation reaction and may nucleate it at the interface, where the stress is likely to be highest.

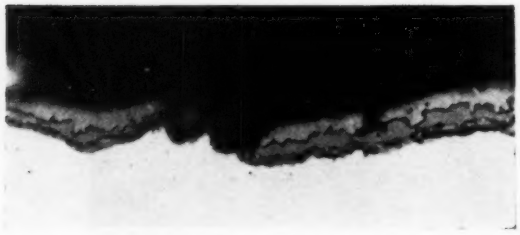


13 *Electron diffraction pattern of scale shown in Fig.12; diffuse rings indicate presence of a fine magnetite precipitate*

Although there is no definite proof of stress-induced nucleation, there are some structural features of the magnetite seam that may be interpreted as illustrations of the importance of stress at the interface. One is the porosity sometimes observed in the magnetite and illustrated very clearly in Fig.5. If the initial precipitation of magnetite from the wüstite relieves the compressive stress at the interface, further growth of magnetite from these nuclei would lead to continued contraction and may be responsible for the formation of small cavities.

Another significant observation is the cracking of the scale adjacent to the seam in Fig.7. The scale beneath the gap adheres to the substrate across the intervening magnetite seam. The scale further away from the gap, which had grown as an adherent layer, has separated from the substrate and has no magnetite seam at the interface; unless cracking occurred during preparation of the specimen the crack must have formed during cooling under the influence of the stress system at the interface. Presumably cracking did not occur under the gap because the internal stress was appreciably lower than under the thick adherent scale. It is possible to regard cracking and the formation of a magnetite seam as alternative methods of accommodating the stress at the interface; a high stress leads to cracking, but if the stress has already been partly relieved by the formation of a gap at an earlier stage, the lower level of stress built up under the thinner adherent layer may be effectively relieved by local magnetite formation.

The third possibility of nucleation at the interface is based on the suggestion that an adherent scale layer prevents the escape of CO and CO_2 from the metal surface and thus suppresses decarburization.[26] This implies equilibrium between the activity of carbon in



14 *Adherent scale after 10% plastic deformation. Hot-rolled rod* ×1000

solution in the steel and the scale; it follows that there must be some solubility of carbon in wüstite, however low the actual figure. Carbon contents of scales are not widely reported in the literature: published figures for scale on mild steel (up to 0·2%C) vary from as low as 0·028%C[6] to a range from 0·26 to 1·20%.[27] Whatever the actual carbon content of the scale, if the wüstite is saturated the activity of the carbon will be equivalent to that of pure carbon. It is quite likely that wüstite with carbon in solution is less stable than relatively pure wüstite and that the carbon gradient through the scale is steep, with the highest carbon content at the scale/metal interface. Breakdown of the wüstite might therefore be initiated at this interface; the reaction might be expressed by the equation:

$$12FeO(C) \rightarrow 3Fe_3O_4 + Fe_3C;$$

this has a negative free energy. Once this reaction has occurred and some magnetite has formed at the interface, it might nucleate continued decomposition of the wüstite according to the normal equation.

There is no evidence that cementite is in fact present at the scale/metal interface, but the proportion of cementite in the original magnetite nuclei would only be one quarter, so that the amount in the final magnetite seam may well be too small to detect.

PRACTICAL CONSIDERATIONS

It is now possible to consider the relevance of the magnetite seam, in the light of its probable origin, to pickling and to mechanical descaling. No direct evidence of the influence of the magnetite seam on pickling is available. It is generally accepted[28] that wüstite is attacked more rapidly by pickling solutions than magnetite and that the scale is undermined by attack along the interface; there is a galvanic cell between the wüstite and the metal which greatly accelerates solution of wüstite as long as it is in contact with the metal.[29] Rapid pickling is favoured, therefore, by a scale in which wüstite is immediately adjacent to the steel and the presence of a magnetite seam at the interface would be expected to slow down the pickling process. It is a common experience that rapid cooling after hot rolling, which would be expected to suppress the decomposition of wüstite, facilitates and accelerates pickling,[30–32] and this has been confirmed in experiments in which the scale thickness was kept constant.[33]

In mechanical descaling, too, faster cooling of the coils after rolling has been shown to be beneficial.[32] The theoretical explanation of the detrimental effect of the magnetite seam is less obvious with mechanical descaling than with pickling, but the observations of scale cracking in the previous section may throw some light on this question. It has been shown in Fig.7 that the scale may adhere where there is a magnetite seam and crack away in adjacent areas. Whatever the actual cause of cracking, scale has spalled off more easily under stresses due to cooling or handling when the seam was absent. Retention of the scale in areas where there is a magnetite seam after 10% tensile deformation is illustrated in Fig.14.

CONCLUSIONS

Possible explanations of the origin of the magnetite seam have been considered in the light of published information and the micrographs presented in this paper. The evidence points to nucleation at the interface of magnetite precipitation from the wüstite. Figures.10–13 provide some support for a nucleation mechanism of magnetite deposition at the metal/scale interface. From the point of view of wüstite composition, preferential initiation of the decomposition in the iron-rich area near the metal seems unlikely. However, the zone close to the interface is known to be enriched in some of the other elements in the steel; these elements may lower the stability of wüstite so that it decomposes more readily near the interface. A factor which might provide added stimulus to the decomposition is the high compressive stress in the wüstite at the interface. Furthermore, any residual magnetite from the healing of an oxidation gap might nucleate the decomposition of wüstite.

There is no direct evidence on the influence of the magnetite seam on pickling and mechanical descaling. Where there is a seam of magnetite at the interface the scale may be more adherent and so cause inefficient mechanical descaling. The seam would also be expected to slow down the pickling process.

ACKNOWLEDGMENTS

The authors are indebted to Aeon Laboratories for the preparation of the electron micrographs; to a number of their colleagues at GKN Group Research Laboratory for specialist services; to Mr F. D. Bridge, manager of the Metals Division, for fruitful discussions and advice, and to Dr T. Emmerson, director of research, for permission to publish this paper.

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Correspondence on the letter

Coal-made iron*

Dr **T. P. Colclough** (British Iron and Steel Federation) wrote: It was somewhat surprising to read in a recent *Journal* the letter of Professor Thring under the above title.

The relations between volume, surface, and height given in the letter are, of course, well known. The surprising feature of the letter is that Professor Thring should recommend this new procedure, because it is precisely the basis on which the low shaft furnace, operated under the direction of IRSID, has been built and is being worked. The results so far are, to say the least, not encouraging and the recent development in that particular operation is to use the furnace as a model of a normal furnace rather than to pursue the idea of utilizing coal.

Attention should be drawn to two other aspects of the letter. It is not correct that 'The general trend of blast-furnace design has been to make them taller and narrower in proportion . . .'. The general trend has been precisely what Professor Thring is advocating, namely, to produce more iron by increasing the hearth area while not increasing the height. The modern 32 ft furnaces have a hearth area of roughly two-and-a-half times the hearth area of the first 20 ft furnace at Corby but the increase in working height is only of the order of some 10%.

The second point is even more important. The whole trend of blast-furnace operation has been in the direction of reducing the coke rate and inevitably reducing the volume of blast-furnace gas made per ton of iron and the calorific value of this gas. The effort has been to increase the effective use of the thermal value of the vital but high cost coke. The suggestion to revert to the old practice of making the blast-furnace an inefficient gas producer must demand careful scrutiny. In this connexion, it is important to note that the possible economic uses of blast-furnace gas in a steelworks are rapidly diminishing. It has been amply demonstrated that it is far more efficient to use liquid and high-grade gaseous fuels for heating purposes in the steelworks than to use low-grade blast-furnace gas or medium-grade producer gas. In the near future there will be no use in the steelworks for any gaseous fuel except those of high calorific value. The only effective use of the gas from the blast-furnace, even using coal instead of coke, will be in the direction of steam-raising, and the economics of using the expensive blast-furnace construction to gasify coal to furnish gas to burn under boilers in place of solid coal direct cannot be accepted without careful scrutiny.

A last point which may be mentioned is that with the modern methods of ore preparation and the control of blowing pressure, blast temperature and the corrective application of steam, regularity of operation is so much improved that the danger of heavy slips and scaffolding is already greatly reduced and no longer presents the problems of the past generation.

AUTHOR'S REPLY

Professor **M. W. Thring** wrote in reply: I think it is important to distinguish between my proposal and a low-shaft furnace, which is essentially a high blast-furnace with the top cut off, but blown at the same rate as the high furnace so that there is a smaller dwell time of the gases and the particles in the chamber. What I am advocating is a furnace with exactly the same reaction volume and the same dwell time of the gases in the chamber and of the particles, replacing height by very large cross-sectional area. I must agree with Dr Colclough in his remarks about general trends in the past, but I am basing my proposal entirely on the question of economics for the future.

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* M. W. Thring: *JISI*, 1960, **194,** Apr., 484.

Colorimetric determination of alumina in iron- and steelmaking slags with Solochrome Cyanine R

P. H. Scholes, A.Met., L.I.M., and Miss D. Valerie Smith

SYNOPSIS

The application of the dye Solochrome Cyanine R to the analysis of slags has been examined and a method is proposed for the rapid determination of alumina in the range 0·15–4·5% with a standard deviation of 0·10%. The sample is dissolved in a mixture of hydrochloric and perchloric acid, and silica is removed by filtration. After separation of interfering elements using sodium hydroxide, the solution is carefully neutralized and the Solochrome Cyanine R–aluminium complex developed under controlled conditions. By means of a slightly modified colour development procedure, samples containing 4–22% alumina may be determined with a standard deviation of 0·25%. 1818

INTRODUCTION

IN CONNEXION with a research project on oxygen in steelmaking under investigation at BISRA, there is an urgent need in the Metallurgy (General) Divisional Analytical Laboratory for a rapid and reliable method for the determination of alumina in a wide range of open-hearth and electric arc furnace slags.

The composition of the slag samples handled by the laboratory, including occasional ironmaking slags, varies between the following limits:

	%		%
Silica	5–50	Magnesium oxide	0·5–17
Calcium oxide	5–60	Phosphorus pentoxide	up to 23
Alumina	0·5–18	Sulphur	up to 2
Manganese oxide	0·5–22	Titanium dioxide	up to 1
Total iron	1–35	Vanadium pentoxide	up to 1

In addition, slags contain small quantities of some of the alloying elements present in the molten bath, particularly chromium. Fluorspar is often added, in which case the fluorine remains in the slag as fluoride or as fluosilicate and in exceptional cases as much as 5% fluorine may be present in the sample.

Four possible approaches to the problem of developing a rapid method for alumina have been considered.

The volumetric aluminium fluoride method developed by Clarke[1] of the British Cast Iron Research Association has been shown to be satisfactory for most normal cupola slags but when applied to slags with a very high iron and/or manganese content the author recommends that a mercury cathode separation should be carried out before solvent extraction of interfering elements with sodium diethyldithiocarbamate. In addition, phosphorus pentoxide, which is usually low in acid cupola slags, begins to have a significant effect when present in large amounts, but the author states that up to 15% of phosphorus pentoxide would not cause any significant error in the alumina result.*

The simplified gravimetric oxine method[3] developed in the laboratories of the British Ceramic Research Association for the rapid analysis of some silicate materials is limited to samples containing less than 4% total iron. The authors state that the precipitation of aluminium by oxine is inhibited by a high silica/alumina ratio. This makes the method unsuitable for steelmaking slags with low alumina contents. It also seems likely that magnesium oxide in amounts normally present in iron- and steelmaking slags will result in some co-precipitation of aluminium during the sodium hydroxide separation.

Shapiro and Brannock[4] have described methods for the rapid analysis of silicate rocks. Their method for the determination of alumina is based upon the formation of a coloured lake or complex of aluminium with

Paper MG/D/221/59 of the Methods of Analysis Committee of the Metallurgy (General) Division of the British Iron and Steel Research Association, received 5 April 1960. The views expressed by the authors are not necessarily endorsed by the Committee as a body.

The authors are at the Association's Sheffield Laboratories.

* In a private communication, Mr Clarke states that experience gained since the aluminium fluoride method[1] was published has indicated that it is quite easy to remove up to 0·2 g of iron and manganese with diethyldithiocarbamate. Since only 0·25 g of sample is taken for the determination, these limits are unlikely to be approached. Thus the modified method[2] should be equally suitable for the determination of alumina in steelmaking slags with high manganese and iron contents.

alizarin red S in the presence of calcium. An empirical correction for titanium interference must be applied. The authors claim that the effect on iron can be eliminated by the formation of ferrous ferricyanide in the sample solution prior to the addition of the dye. Trials with this method indicated that if more than about 20 μg of iron is present during colour development (equivalent to 2% in the sample) the blue colour of the ferrous ferricyanide interferes with the measurement of the aluminium–dye complex. If, in addition to iron, manganese is present, a muddy brown colour is produced. The optical density of the combined manganese–iron background colour is erratic and not sufficiently reproducible to enable compensation solutions to be used. The low sensitivity of the colour reaction and the high blank values varying between 0·5 and 0·6 density units in a 4-cm cell prove further limitations of the method.

Eriochromcyanin R has been used extensively in Germany for the colorimetric determination of aluminium in ferrous metals. In 1952, Bacon[5] examined a British dye, Solochrome Cyanine RS, stated to be similar in properties to Eriochromcyanin R, and successfully developed a method for the determination of aluminium in magnesium alloys. Subsequently the present authors[6] used a somewhat purer dyestuff, Solochrome Cyanine R, for the determination of aluminium in steel. The method incorporates a preliminary mercury cathode separation followed by treatment with sodium hydroxide to remove elements which interfere in the formation of the aluminium–dye complex. Recent work by Hill[7,8] with the dye Eriochrome Cyanine R suggests that interference due to iron and certain other heavy metals may be overcome by complexing with either thioglycollic acid or ascorbic acid. The present authors found that the presence of thioglycollic acid inhibits the colour development somewhat and gives non-reproducible results: ascorbic acid causes the optical density of the aluminium–dye complex to fade rapidly and considerably impairs the precision of the procedure.

It was concluded that a preliminary separation of iron and manganese followed by colour development with Solochrome Cyanine R based on the authors' previous paper[6] would provide the best approach to the determination of alumina in slags.

DECOMPOSITION OF THE SAMPLE

Several recommended methods for the rapid dissolution of slags have been examined. One of the best of these is the method proposed by Clarke[2] for the analysis of cupola slags. This consists of dissolution of the sample with a mixture of hydrofluoric, nitric, and perchloric acid in a large platinum dish which is suspended in a radiation bath. It is necessary to remove the hydrofluoric acid since it bleaches the aluminium–dye complex; its complete removal is effected by fuming the solution strongly for 5 min, diluting with water and repeating the fuming treatment for a further period of 5–10 min. This treatment leads to the formation of insoluble compounds which may be redissolved only with considerable difficulty. Digestion with hydrochloric acid followed by a third evaporation to fuming with perchloric acid seems to decompose most of the residue, but a small amount of material remains undissolved after treatment with the above mixed acids in most steelmaking slags, especially those containing appreciable amounts of alumina and/or manganese oxide. This residue must be filtered off, ignited, treated with hydrofluoric acid and sulphuric acid, and finally brought into solution by fusion with sodium carbonate.

Consideration was also given to the dissolution procedure used by the Raw Materials, Slags and Refractories Analysis Sub-Committee (MG/DA) of BISRA[9]. The slag is dissolved by the slow addition of hydrochloric acid to a suspension of the sample in boiling water. The solution is then oxidized with nitric acid and evaporated to fuming with perchloric acid; the silica is removed by filtration and then volatilized with hydrofluoric acid in the presence of sulphuric acid. After a sodium carbonate–borax fusion, the residue is extracted in dilute acid and added to the main solution. This procedure is only slightly longer than the BCIRA procedure when applied to steelmaking slags; the use of hydrofluoric acid in the initial solvent acid is avoided and thus there can be no danger of its incomplete removal due to an inadequate fuming treatment with perchloric acid. Experience has shown that this procedure is highly satisfactory, providing complete dissolution of a wide variety of steelmaking slags.

SEPARATION OF ALUMINIUM

The ratio of iron to alumina in slag permits of a direct sodium hydroxide separation of iron and manganese without the danger of absorption of aluminium on the hydroxide precipitate. The mercury cathode procedure of the authors' earlier paper[6] is now omitted.

In the proposed method, an aliquot containing 5 mg of the dissolved sample is treated with sodium hydroxide and hydrogen peroxide to remove iron and manganese. Separation of iron is much improved if the sample contains more than 10% manganese oxide. The precipitate then coagulates rapidly and filters more easily. To ensure that the manganese content is adequate an addition of 1 mg of manganese before separation is incorporated in the procedure. In the authors' earlier work it was shown that after separation with sodium hydroxide, satisfactory results could be obtained by taking an aliquot containing 2–70 μg of aluminium and developing the aluminium–dye complex under carefully controlled conditions. Further experience has shown that maximum reproducibility of colour development is obtained when the range is limited to 2–60 μg of aluminium, equivalent to 4–113 μg of alumina. In the proposed procedure for the determination of alumina, an aliquot containing 2·5 mg of sample is taken from the filtrate after separation to cover a range of 0·15–4·5% alumina. The procedure was slightly modified to extend the range of the method to cover slags containing 4–22% alumina. In this case an aliquot containing 0·5 mg of sample is taken from the filtrate and the procedure for colour development is similar to that originally used for the analysis of steel.

INTERFERENCE EFFECTS

The interference effects of calcium oxide, phosphorus pentoxide, and magnesium oxide have been studied using synthetic solutions. In addition the effect of the following constituents has been studied: perchloric acid introduced during the dissolution procedure, chromic oxide which is sometimes present in electric arc furnace slags, and fluorine.

TABLE I Recovery of alumina from synthetic slag sample, low-range method

Alumina added, mg	%	Alumina found, %	Error, %
0·75	0·15	0·16	+0·01
		0·21	+0·06
1·5	0·30	0·30	Nil
		0·37	+0·07
4·5	0·90	0·87	−0·03
		0·90	Nil
6	1·20	1·24	+0·04
		1·28	+0·08
12	2·40	2·24	−0·16
		2·34	−0·06
		2·40	Nil
15	3·00	2·90	−0·10
		3·01	+0·01
		3·11	+0·11
		3·07	+0·07
22·5	4·50	4·59	+0·09
		4·46	−0·04
		4·43	−0·07
		4·62	+0·12

TABLE II Recovery of alumina from synthetic slag sample, high-range method

Alumina added, mg	%	Alumina found, %	Error, %
20	4	3·8	−0·2
		4·2	+0·2
40	8	7·9	−0·1
		8·1	+0·1
60	12	11·9	−0·1
		11·8	−0·2
		12·0	Nil
		12·3	+0·3
85	17	16·9	−0·1
		17·3	+0·3
110	22	21·8	−0·2
		22·0	Nil
		21·8	−0·2
		22·2	+0·2

Calcium oxide

The presence of up to 5 mg of calcium oxide does not interfere with the colour development procedure.

Phosphorus pentoxide

Bacon[5] noted that phosphates interfere in the colour development when using the dye Solochrome Cyanine RS. This was confirmed by the present authors who found that phosphorus pentoxide present in amounts greater than 0·9 mg in the aliquot taken for colour development has a depressive effect on the formation of the aluminium–dye complex. Provided that this level is not exceeded there is no interference from phosphorus pentoxide in the 'high-range method' but in the 'low-range method' its concentration should not exceed 36%.

Magnesium oxide

Aluminium is partially precipitated during the sodium hydroxide separation if magnesium is present in the solution. If, however, the aliquot taken for separation contains at least 0·5 mg of iron and the magnesium oxide content does not exceed 0·8 mg, recovery of aluminium is complete. The magnesium oxide content of the sample must not be greater than 16%; this value is rarely exceeded in practice but in exceptional cases a smaller aliquot must be taken from the main solution. To ensure that the iron content is adequate in preventing loss of aluminium during the sodium hydroxide separation, an addition of 0·5 mg of iron is incorporated in the procedure.

Perchloric acid

The presence of up to 0·5 ml of perchloric acid (as sodium perchlorate) in the aliquot taken for colour development is without effect. In the proposed procedure the aliquot will not contain more than the equivalent of 0·1 ml of perchloric acid.

Chromic oxide

After separation with sodium hydroxide in the presence of hydrogen peroxide, chromium is present as sodium chromate. Tests indicate that up to 75 μg of chromic oxide (Cr_2O_3) taken for colour development is without effect, but low results are obtained if this concentration is exceeded. In the high-range method, therefore, a concentration of up to 15% chromic oxide may be tolerated and up to 3% in the low-range method.

After separation a further addition of hydrogen peroxide is made to the acidified solution to complex any titanium present in the slag. If chromium is present, a blue coloration of perchromic acid is formed which rapidly decomposes to give the green chromic salt. The first appearance of this coloration coincides with the tolerance level and thus provides a warning of chromium interference.

Fluorine

Fluorine (as sodium fluoride) bleaches the colour of the aluminium–dye complex if more than 10 μg is present in the aliquot taken for colour development. Tests established that fuming with perchloric acid at a temperature that will maintain a steady reflux of acid on the sides of the beaker removes the greater part of the fluorine in fluorine-containing slags, leaving only 0·1–0·2% in the solution. As the fluorine content of the slag samples is not always known it was considered advisable to incorporate a fuming treatment in the procedure as a safeguard and remove fluorine in every case.

RESULTS

The proposed method for the determination of alumina in slag which is described in the Appendix, was tested by making additions of standard aluminium solution to a synthetic slag solution. The results obtained with the low-range method (0·15–4·5%) are given in Table I and show a mean error of ±0·06% alumina. The results obtained with the high-range method (4–22%) are given in Table II and show a mean error of ±0·16% alumina. The composition of the synthetic sample is shown in Table III.

The method was then applied to four samples of iron- and steelmaking slag previously analysed by the MG/DA Sub-Committee using their recently developed oxine procedure.[9] In addition, the authors' method was applied to a sample of cupola slag previously analysed by the BCIRA Methods of Analysis Sub-

TABLE III Composition of synthetic slag sample

	Wt, mg	Equivalent
Calcium oxide	200	40
Magnesium oxide	50	10
Phosphorus pentoxide	50	10
Ferric oxide	50	10
Chromic oxide	10	2
Manganese oxide	25	5
Vanadium pentoxide	5	1
Titanium dioxide	5	1
Fluorine	10	2

TABLE IV Comparison between volumetric and proposed methods for determining alumina

Sample no.	Methods of Analysis Committee results and range, %	Results by proposed method: Individual results, %	Mean, %	Std deviation, %
MGS 296 Corby blast-furnace slag	19·77 (19·57–19·95)	19·2, 19·3, 19·2, 19·3, 19·4, 19·8, 19·8, 19·6	19·5	0·25
MGS 267 blast-furnace slag	15·63 (15·45–15·75)	15·5, 15·5, 15·5, 15·7, 15·8, 15·7, 15·4, 15·4	15·6	0·16
MGS 346 Fluorine slag	1·94 (1·84–2·06)	1·85, 1·90, 1·95, 1·90, 2·10, 1·85, 1·75, 1·90	1·90	0·10
MAS 128 Cupola slag	9·6* (9·4–9·8)	9·3, 9·4, 9·5, 9·5, 9·3, 9·6	9·4	0·12
MGS 268 Basic OH slag	1·82 (1·78–1·92)	*Operator A:* 1·85, 1·80, 1·65, 1·65, 1·75, 1·80, 1·65, 1·70	1·75	0·08
		Operator B: 1·80, 1·70, 1·65, 1·75, 1·90, 1·80, 1·65, 1·85	1·75	0·09

* Results obtained by the BCIRA Methods of Analysis Sub-Committee.

Committee using a fluoride volumetric method.[1] The results obtained are compared with members' results[10,11] in Table IV. The approximate compositions of the five slag samples are given in Table V.

Samples MGS/296 and 267, and MAS/28 were analysed by the high-range method: the individual results were rounded off to the nearest 0·10% and gave a maximum standard deviation of 0·25% alumina. Samples MGS/346 and 268 were analysed by the low-range method: the individual results were rounded off to the nearest 0·05% and gave a maximum standard deviation of 0·10% alumina. Results obtained by the two methods show good agreement, with the possible exception of MGS/296 where the mean value is somewhat lower than members' results. The precision obtained is considered to be satisfactory for a colorimetric method which depends upon the formation of an aluminium complex with a dyestuff.

CONCLUSIONS

A method has been developed in which the formation of a coloured complex between aluminium and Solochrome Cyanine R can be applied to the determination of alumina in iron and steelmaking slags over the range 0·15–22%. Chromic oxide and magnesium oxide interfere with the method but in each case the maximum permissible content of these elements is sufficiently high to render the method applicable to a very wide range of slag compositions.

The method is more rapid but somewhat less precise than the conventional volumetric oxide method. It is particularly suitable for the analysis of large batches of slag samples for production control and also for research into steelmaking processes.

ACKNOWLEDGMENTS

The authors are indebted to members of the BISRA Raw Materials, Slags and Refractories Methods of Analysis Sub-Committee for their interest and helpful criticisms, and also for the provision of samples. They also wish to express their grateful thanks to Mr R. Loxley who undertook trials of the procedure.

TABLE V Approximate percentage composition of samples

	MGS/267	MGS/268	MGS/296	MGS/346	MAS/28
Silica	30	14	34	...	48
Calcium oxide	41	45	31	...	28
Magnesium oxide	8	7	7	...	2
Phosphorus pentoxide	0·2	12	...	...	...
Ferric oxide	...	6	...	...	...
Ferrous oxide	...	5	0·8	...	4
Manganese oxide	0·6	5	1	...	2
Vanadium pentoxide	...	1	...	...	...
Titanium dioxide	0·5	0·7	0·7	...	2
Fluorine	...	...	...	5	...

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APPENDIX

Method of analysis

Principle

The sample is dissolved in a mixture of perchloric acid and hydrochloric acid, and silica is removed by treatment with hydrofluoric acid. After separation of interfering elements using sodium hydroxide, the solution is carefully neutralized and the aluminium–Solochrome Cyanine R complex is developed under controlled conditions.

Range

Low-range method: 0·15–4·5% alumina
High-range method: 4–22% alumina.

Rounding results

Low range: Round off individual results to the nearest 0·05%
High range: Round off individual results to the nearest 0·1%.

Reagents

All solutions must be prepared from reagents of the highest purity obtainable. Dilute acid solutions and caustic solutions should be stored in polythene bottles.

Sodium hydroxide (16% w/v) Transfer 160 g of AnalaR sodium hydroxide pellets to a 1 l. polythene bottle, add 900 ml of water and partly immerse the bottle in cold running water. Shake until the pellets are dissolved, cool and dilute to 1 l. in a polythene measuring cylinder.

Sodium hydroxide (8% w/v) Dilute 50 ml of 16% w/v sodium hydroxide to 100 ml.

Solochrome Cyanine R solution (0·1% w/v) Dissolve 0·10 of BDH Solochrome Cyanine R in exactly 100 ml of water and filter through a Whatman no.541 filter paper into a dry 4 oz. amber stoppered bottle.

Solochrome Cyanine R solution (0·5% w/v) Dissolve 0·10 g of BDH Solochrome Cyanine R in exactly 20 ml of water. Filter through a Whatman no.541 filter paper into a dry 1 oz. amber stoppered bottle. (Merck Eriochromcyanin R specified 'For determination of aluminium' may also be used (*see footnote, p.*195).

The dye solutions must be prepared daily and set aside for at least 1 h before use. Glassware that has been in contact with these solutions should be rinsed with nitric acid and washed thoroughly with water before use.

Buffer solution, concentrated Dissolve 275 g of ammonium acetate and 110 g of hydrated sodium acetate in 1 l. of water. Add exactly 11 ml of glacial acetic acid and mix thoroughly.

Buffer solution, dilute To 1 vol of concentrated buffer solution add 5 vol of water and adjust the pH to 6·10±0·05 by adding acetic acid or sodium hydroxide solution.

Fusion mixture Thoroughly mix 3 parts of sodium carbonate with 2 parts of anhydrous borax.

Standard aluminium solution Dissolve 0·7937 g of high purity aluminium in hydrochloric acid, add 20 ml of perchloric acid, evaporate to fuming and dilute to 1 l. in a calibrated flask.

1 ml = 1·5 mg Al_2O_3

Dilute standard aluminium solution Dilute 100 ml of standard aluminium solution to 500 ml in a calibrated flask

1 ml = 300 μg Al_2O_3

Manganese solution Dissolve 4·1 g of manganese sulphate ($MnSO_4.4H_2O$) in 100 ml of water and dilute to 1 l.

1 ml = 1 mg Mn

Iron solution Dissolve 0·5 g of high-purity iron in 20 ml of hydrochloric acid and dilute to 1 l.

1 ml = 0·5 mg Fe

Procedure

Decomposition of the sample

Transfer 0·5 g of sample (ground to pass a B.S. no.85 mesh sieve and dried at 105°C to constant weight) to a dry 250 ml beaker, add 10 ml of water and heat to boiling. To the boiling solution, slowly add 20 ml of hydrochloric acid (sp. gr. 1·16–1·18) at such a rate that the boiling is maintained, and oxidize with nitric acid (sp. gr. 1·42). Add 15 ml of perchloric acid (sp. gr. 1·54), cover the beaker with a clock-glass and evaporate to fuming. Continue fuming for 10 min at a temperature that will maintain a steady reflux of acid on the walls of the beaker. Cool, add 10 ml of hydrochloric acid and digest until all soluble salts are dissolved. Add 50 ml of hot water, swirl the solution, and filter through a paper-pulp pad, washing alternately with hydrochloric acid (5% v/v) and hot water. Reserve the filtrate.

Ignite the pad and precipitate in a platinum dish at about 700°C. Cool, moisten the residue with a few drops of water, add 0·5 ml of sulphuric acid (25%v/v), 10 ml hydrofluoric acid and evaporate to dryness under an infra-red lamp. Remove the last traces of sulphuric acid by heating on the hot plate and then heat at about 700°C for 5 min. Cool, place 2 g of fusion mixture in the platinum dish, heat at the mouth of the muffle furnace for 10 min and then fuse for 20 min at 1000°C. Cool, cautiously add 10 ml of hydrochloric acid (20% v/v), place a clock-glass on the dish and heat gently on the hot-plate until effervescence ceases. Transfer the solution into a 125 ml beaker and repeat the extraction twice or until all the residue is removed from the dish. Boil the solution to ensure complete dissolution of the residue, cool and add to the main filtrate. Dilute the solution to 1 l. and store in a polythene bottle.

Sodium hydroxide separation

Transfer a 10 ml aliquot (note 1) to a 200 ml stainless steel beaker (note 2) containing 25 ml of sodium hydroxide solution (16% w/v), add 1 ml of iron solution, 1 ml of manganese solution, and 5 ml of hydrogen peroxide (5 vol). (It is essential to use high-purity hydrogen peroxide for the preparation of dilute solutions: AnalaR grade is suitable.) Cover the beaker with a clock-glass, heat to boiling point and boil gently for 10 min. Remove the beaker from the hot plate, add a little paper pulp and set aside for 5 min. Filter through a tight paper-pulp pad (in a polythene funnel) into a 200 ml polythene beaker. Wash the pad thoroughly with small volumes of warm water allowing the pad to drain completely between each wash. A total of 100 ml of water will be required. To the filtrate add 15 ml of hydrochloric acid (50% v/v), two drops of phenolphthalein indicator and complete the neutralization to the change point of the indicator with a dropwise addition of hydrochloric acid (50% v/v). Stir the solution during neutralization with a polythene rod and add 0·5 ml of hydrochloric acid (50% v/v) in excess. Cool the solution.

Colour development

High-range method For samples containing 4–22% Al_2O_3.

Dilute the solution to 200 ml in a calibrated flask (note 3) and transfer a 20 ml aliquot to a 250 ml beaker (note 4) (For batch analysis the number of aliquots taken for colour development should be restricted to eight including a reagent blank.) To the aliquot add 5 ml of hydrogen peroxide (5 vol) and mix well. Neutralize carefully by the addition of sodium hydroxide solution (8% w/v) from a polythene dropping bottle and add one drop in excess. Titrate immediately with 0·2 N hydrochloric acid, add exactly 1·0 ml of acid in excess and mix thoroughly. Add exactly 5·0 ml of Solochrome Cyanine R solution (0·1% w/v), mix, add 50 ml of dilute buffer solution and dilute to 100 ml in a calibrated flask without delay.

Low-range method For samples containing 0·15–4·5% Al_2O_3.

Transfer the filtrate to a 500 ml beaker (note 3), insert a boiling rod and evaporate to about 90 ml. Cool, dilute to 100 ml in a calibrated flask and transfer a 50 ml (note 4) aliquot to a 250 ml beaker. Add 1 ml of hydrogen peroxide (25 vol) and mix well. Carefully neutralize with sodium hydroxide solution and dilute acid as described above. Add exactly 1·0 ml of Solochrome Cyanine R solution (0·5% w/v) from a 10 ml semi-micro burette, mix, add 45 ml of dilute buffer solution and dilute to 100 ml in a calibrated flask without delay.

Measurement of optical density

Set the solution aside for 30 min and then measure the optical density against a reagent blank solution in 5-mm cells with a spectrophotometer at wavelength 535 mμ. Reset the instrument against the blank solution before each sample solution is measured. The optical density of the blank solution is approximately 0·17 for the high-range method and 0·25 for the low-range method.

Optical density measurements can also be made with an absorptiometer. An instrument with a mercury-vapour lamp using Ilford 605 and Calorex H 503 filters is suitable, the sensitivity is reduced by about half and it is necessary to measure optical density in 1-cm cells. In these circumstances, the optical density of the blank solution is about 0·25 for the high-range method and 0·35 for the low-range method. If measurements are made with a Hilger photoelectric absorptiometer, the 'zero setting' method should be used in preference to the 'water setting' method.[12]

Each batch of test solutions must be accompanied by a reagent blank solution. The blank determination may be simplified by omitting the residue treatment; the fusion mixture should instead be dissolved directly in the filtrate.

Calibration

Low-range method

To six beakers, add the following reagents: 1 ml of perchloric acid (sp. gr. 1·54), 6 ml of hydrochloric acid (20% v/v), and 10 ml of water. To each solution, add standard alumina solution according to the following schedule:

Volume of dilute standard aluminium solution (1 ml = 300 μg Al_2O_3), ml	Equivalent alumina, %
Nil	Nil
1	0·6
2	1·2
4	2·4
6	3·6
8	4·8

Dilute each solution to 100 ml in a calibrated flask. Take a 10 ml aliquot and finish as described under 'sodium hydroxide separation'.

High-range method

Proceed as described in the low-range method calibration but using the standard aluminium solution according to the following schedule:

Volume of standard aluminium solution (1 ml = 1·5 mg Al_2O_3), ml	Equivalent alumina, %
Nil	Nil
1	3
2	6
4	12
6	18
8	24

For the batches of BDH dyestuff* used in the authors' laboratory, it was found that the calibration graphs intersected the concentration axis at 0·2% in the high-range method and 0·05% in the low-range method. The factors obtained by the authors with a Unicam SP 600 spectrophotometer are given below:

For the range 0·15–4·5% Al_2O_3:
($d_s$mm × 5·84) + 0·05 = % Al_2O_3.
For the range 4–22% Al_2O_3:
($d_s$mm × 26·6) + 0·2 = % Al_2O_3.

These factors are intended as a guide only; specific factors must be determined for individual instruments.

The authors have at times noticed a slight drift in the slope of the calibration curves when using BDH Solochrome Cyanine R. Thus it is recommended that the calibrations should be checked occasionally, say, once a week. For this purpose two calibration points and a reagent blank are adequate for each range. Suitable points are 1·2% and 3·6% for the low-range method and 6% and 18% for the high-range method. It is also advisable to check the calibration curves with each new batch of dyestuff.

NOTES

1. The aliquot taken for the sodium hydroxide separation must not contain more than 0·8 mg of magnesium oxide. If the sample contains more than 16% magnesium oxide, a smaller aliquot should be taken.
2. A blue film is formed on the walls of stainless-steel beakers which have been in constant use for some time. This film, which is presumably a corrosion product, may easily be removed by momentary treatment with nitric acid. The beakers should then be boiled out with sodium hydroxide solution (8% w/v) before use.
3. To avoid contamination from other sources it is recommended that glassware should be set aside for the colour development procedure. This glassware should not be used for any other purpose in the laboratory.
4. The aliquot taken for colour development must not contain more than 75 μg of chromic oxide. In the high-range method, therefore, a concentration of up to 15% chromium trioxide may be tolerated and up to 3% in the low-range method. If these contents are exceeded, a smaller aliquot should be taken for the sodium hydroxide separation.

* Since the work on this method was completed, the authors have had an opportunity of testing Merck Eriochromcyanin R specified 'for determination of aluminium'. Calibration graphs prepared with this reagent intersect the origin; the slope is practically identical with Solochrome Cyanine R graphs but the blank value is slightly lower. Merck reagent is obtainable from Anderman and Co. Ltd, 87 Tooley Street, London SE1.

Desulphurization of basic electric arc furnace steel by the injection of powdered materials

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INTRODUCTION

THE REFINING PERIOD in the electric arc furnace, i.e. when the molten metal is held under a reducing slag for sulphur removal, is the time when the hydrogen content of the steel can increase to undesirable levels. For very low sulphur steels extremely long refining times are necessary and the present investigation was conducted with the aim of reducing these times with consequent increase in productivity and a reduced possibility of hydrogen pick-up.

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The authors are at the BISRA Sheffield Laboratories.

SYNOPSIS

Rapid desulphurization of steel to very low levels has been achieved by the injection of powdered desulphurizing agents directly into the metal bath of a basic electric arc furnace. The work which has been carried out at BISRA using this technique is reviewed and an indication is given of the cost of the materials used. 1844

The equilibrium distribution of sulphur between slag and metal depends upon the basicity of the slag and the degree of oxidation of the system.[1–3] The rate at which this distribution is approached is governed at constant temperature by the rate of diffusion of the reaction products from the slag/metal interface into the bulk of the slag,[4,5] and by the area of contact of the slag and metal.[6]

TABLE I Typical analyses of injected alloys

	Calcium–silico–magnesium, %	Calcium–silico–manganese, %	Calcium silicide, %
Si	54·9	50·5	60·3
Ca	30·1	16·2	32·3
Mg	10·3	...	...
Mn	...	21·8	0·025
Al	1·4	1·3	1·9
Fe	2·6	9·3	3·5
C	0·4	0·4	...
Ti	...	...	0·09

The injection of a finely divided basic material directly into a metal bath should increase both the degree and rate of desulphurization, since the basicity of the slag produced is high and the area of the slag/metal interface is increased. The slow diffusion of the sulphur in the slag should no longer be a rate-determining step. If the material injected is also a deoxidizer, or if a deoxidant is injected at the same time, then the oxygen content of the metal will be lowered, increasing the degree of desulphurization.

Experiments, therefore, have been carried out in which powdered desulphurizing agents were injected directly into the metal bath of an electric arc furnace at normal steelmaking temperatures. The results of these tests are presented in this paper.

EXPERIMENTAL PROCEDURE

Injection under a minimum of slag

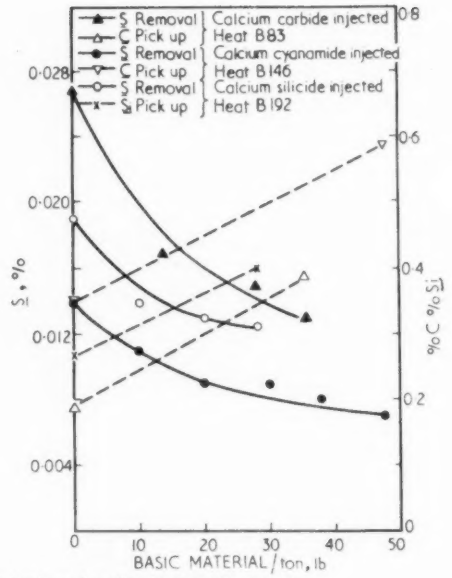
The metal bath was put under a white reducing slag in a 10 cwt electric arc furnace until the sulphur concentration of the metal was reduced to about 0·015%. The slag was then removed almost completely and the desired quantity of powdered reagent, with or without deoxidizer, injected into the bath through $\frac{1}{2}$-in. Class C tubing using 'oxygen-free' nitrogen as the carrier gas. The reaction products from the injection were left on the metal surface to form a new slag. A British Oxygen Gases powder dispenser was used for the injection. In each experiment the lancing was divided into a number of parts to determine the course of reaction.

Eighteen experimental heats were carried out using this procedure and the powdered materials injected were burnt lime, burnt lime plus carbon, calcium cyanamide, calcium carbide, Raremet compound no.5, calcium silicide, and calcium silicide plus burnt lime. Mixtures of the above, together with either powdered aluminium or magnesium, were also injected.

Injection under a white reducing slag

The metal bath was put under a white reducing slag in a 1-ton electric arc furnace and metal and slag samples and temperatures were taken at regular intervals so that the rate of desulphurization for that particular slag could be determined. The desired quantity of powdered reagent was then injected as described above. A metal and a slag sample and a temperature were taken immediately after the injection was completed. In most of the experiments a sample was taken from the ladle after tapping. Hydrogen sampling was carried out in a few of the experiments.

Eighteen experimental heats were conducted using this technique and the materials used for the injections were calcium–silico–magnesium, calcium–silico–manganese, calcium silicide, burnt lime plus magnesium powder, and calcium carbide. Typical analyses of the alloys injected are presented in Table I.



1 *Injections into* Fe–Si *deoxidized baths*

RESULTS

The investigation involved the partial or complete analysis of some 230 individual samples; typical examples are presented in Tables II and III and Figs.1–6. Detailed analytical results of all the experiments conducted may be obtained on application to the authors.

DISCUSSION

When powdered calcium carbide is injected into a metal bath the following reactions occur:

$$CaC_2 + \underline{O} \rightarrow (CaO) + 2\underline{C} \quad \ldots\ldots(1)$$

$$CaC_2 + \underline{S} \rightarrow (CaS) + 2\underline{C} \quad \ldots\ldots(2)$$

Similar reactions occur when calcium cyanamide

TABLE II Typical experiment carried out under a minimum of slag; calcium cyanamide injected into an aluminium deoxidized bath

Heat no.	Action		Temp., °C	Metal analysis, % C	S	Si	Al	Slag analysis, % FeO	Fe_T	CaO	SiO_2	S	Al_2O_3	(S)/S
B119	Reducing slag removed	Sample I	1590	0·44	0·015	0·35	0·021							
	10 lb/ton injected	Sample II	1610		0·009		0·014	1·70	1·45	48·9	24·9	0·60	7·6	67
	10 lb/ton injected	Sample III	1615		0·005		<0·01	1·79	1·54	46·0	29·5	0·40	6·9	80
	10 lb/ton injected	Sample IV	1600		0·005	0·33	0·014							
	8 lb/ton injected	Sample V	1650	0·73	0·006		<0·01	2·10	1·90	42·3	27·8	0·30	8·3	50

Overall reaction: 38 lb calcium cyanamide/ton + 2 lb aluminium/ton removed 0·01%S
Rate of injection: 3·4 lb calcium cyanamide injected/ton/min

TABLE III Typical experiment carried out under white reducing slag conditions; calcium–silico–magnesium injected

Heat no.	Action	Time, pm	Temp., °C	Metal analysis, % C	S	Mn	Si	Slag analysis, % FeO	Fe_T	CaO	SiO_2	S	MgO	(S)/[S]
B387	Metal under 'white' reducing slag													
	Sample I	3·50	1615		0·030	0·25	0·49							
	Sample II	4·00	1615		0·020									
	Sample III	4·10	1620		0·020									
	Sample IV	4·20	1600	0·33	0·015	0·27	0·58	1·21	1·2	50·0	27·0	0·34	10·5	22·7
	20 lb calcium–silico–magnesium injected/ton	$4·22_5$												
	Sample V	4·25	1560	0·35	0·007	0·21	0·97	1·75	1·4	48·3	25·9	0·55	13·5	78·6
	Sample VI	4·29	1560		0·007	0·22	0·96							
	Metal tapped	4·35	1600											
	Sample from the ladle				0·008									

Overall reaction: 20 lb calcium–silico–magnesium injected/ton of metal treated removed 0·008%S, i.e. 2·5 lb injectant/0·001%S removed
Rate of injection: 10·8 lb calcium–silico–magnesium/ton/min
Nitrogen usage: 0·47 ft³ nitrogen used/lb calcium–silico–magnesium injected

and calcium silicide are injected. With lime the reaction is:

$$CaO + \underline{S} \rightarrow (CaS) + \underline{O} \quad \ldots\ldots (3)$$

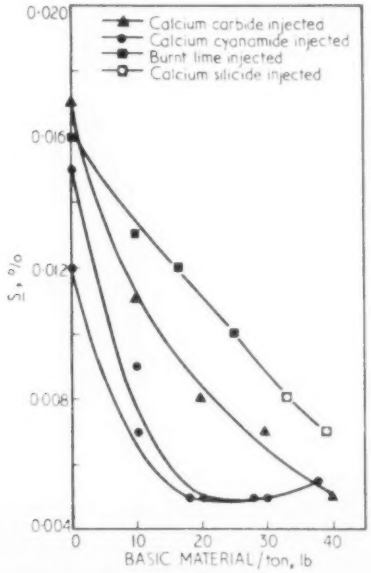
To enable the desulphurizing reaction (2) to occur, the metal bath must be well deoxidized, otherwise the deoxidizing reaction (1) will take place preferentially, the oxide of calcium being much more stable than the sulphide. For lime to be effective equation (3) shows that oxygen must be maintained at a low level.

Aluminium lowers the oxygen concentration of a metal bath far more than ferrosilicon, which accounts for better results being obtained when basic materials, e.g. calcium carbide and calcium cyanamide, were injected into aluminium deoxidized baths (Fig.2) as compared with injection into ferrosilicon deoxidized baths (Fig.1).

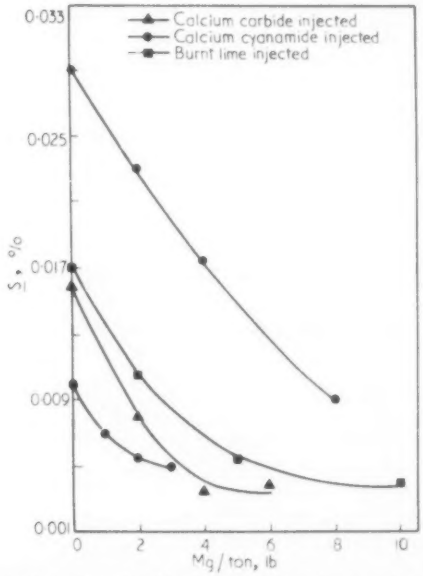
A similar effect was noted when calcium silicide was injected. Figure 2 summarizes all the experiments on injection into aluminium deoxidized baths and shows that reproducible values of about 0·005%S were obtained by injecting either calcium cyanamide or calcium carbide. Burnt lime was the least efficient desulphurizer under these conditions, probably because of the difficulty of removing oxygen rapidly enough to allow reaction (3) to proceed in the time available. In one heat when the metal was analysed for residual aluminium the concentration of aluminium was shown to be less than 0·01%.

Rare earths, either the metals or their oxides, have been reported to be good desulphurizers,[7–9] which is to be expected since the rare earth sulphides are very stable. In the two experiments carried out in which Raremet compound (a mixture of the oxides) was injected, very little sulphur removal occurred at the low sulphur levels studied. These disappointing results are probably due to the fact that desulphurization by injection of an oxide requires the same conditions as for reaction (3).

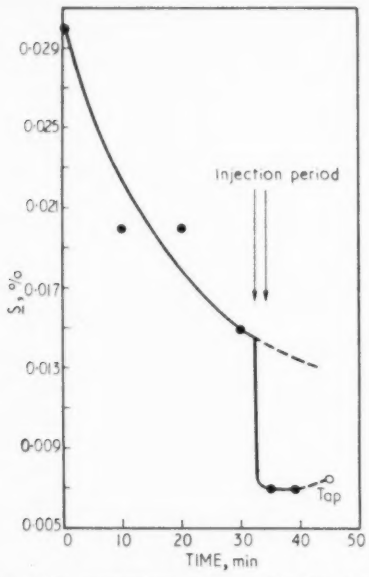
Experiments have been reported[10–12] in which partial desulphurization has been achieved by treating steel with magnesium or magnesium-aluminium alloys. This is to be expected since magnesium, in addition to being a strong deoxidant like aluminium, is also a strong sulphide former in a deoxidized bath. It was decided, therefore, to inject mixtures of powdered basic materials and magnesium powder to bring about



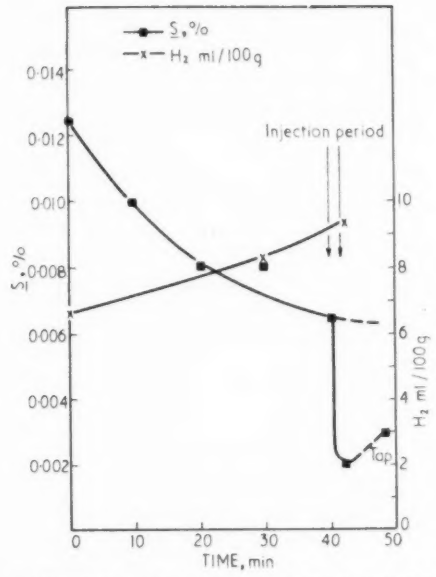
2 *Injections into* Al *deoxidized baths*



3 *Injection of powdered basic materials and magnesium powder into* Fe–Si *deoxidized baths*



4 *Calcium–silico–magnesium under reducing slag (20 lb injected per ton)*



5 *Burnt lime + Mg under reducing slag (24 lb CaO/5·9 lb Mg injected per ton)*

a greater degree of desulphurization. Powdered magnesium when injected into molten metal at high concentrations can result in violent reactions. Frequent blockages of the lance can also occur. When diluted by about four times its weight, of a dense powdered basic material e.g. calcium carbide, or twice its weight, of a light powdered basic material e.g. burnt lime, the mixture can easily be dispensed. Four experiments were carried out in which the magnesium mixtures were injected and a comparative summary of these experiments is shown in Fig.3. This shows that sulphur concentrations of 0·005% and less were easily obtainable by injecting mixtures of calcium carbide, calcium cyanamide, or burnt lime with magnesium powder into ferrosilicon deoxidized baths. Of the mixtures used that of burnt lime and magnesium powder offers the most promise with least deleterious side effects, providing the burnt lime is thoroughly dehydrated.

Injections under white reducing slag conditions were then carried out so that the *rate* of sulphur removal obtainable with a particular reagent could be measured.

An initial experiment was conducted in which 'oxygen-free' nitrogen was blown into the metal bath under a reducing slag. No sulphur removal occurred at a 0·011% sulphur level. Experiments were then carried out using powdered limestone as the injectant into the metal bath under a white reducing slag. A sulphur reversal occurred, the sulphur concentration of the metal bath being increased at a 0·020% initial sulphur level. A possible explanation for this is that the carbon dioxide, produced from the dissociation of the limestone during the injection, oxidized the metal bath, causing the sulphur reversion. To prevent this increase in the oxygen content of the metal, magnesium powder was injected with the limestone. This was, however, insufficient to overcome the oxidizing effect from the breakdown of the carbonate and little sulphur removal occurred.

Following the large degree of desulphurization achieved during the experiments in which mixtures of basic materials and magnesium powder were injected under a minimum of slag, it was decided to inject

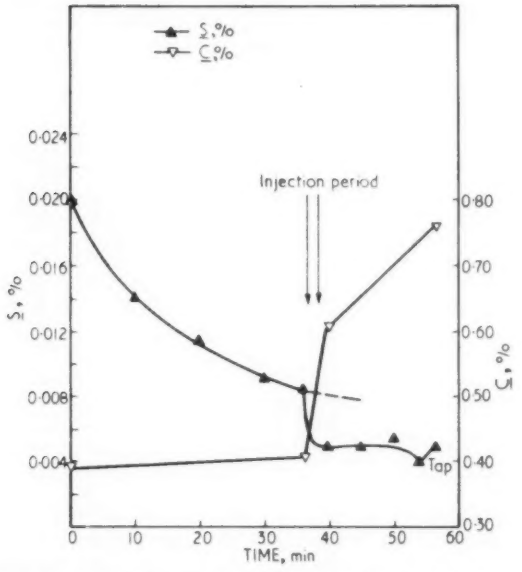
TABLE IV Tapping on to reagents in the ladle

Heat no.	Reagent	Sample	C%	S%	Si%	Mn%	N%
B391	Calcium–silico–magnesium 5 lb/ton	Before tap	0·10	0·028	0·39	0·52	
		After tap		0·028	0·42		
B404	Calcium–silico–magnesium 10 lb/ton	Before tap	0·40	$0·014_5$	0·60		0·0114
		After tap		$0·014_5$	0·67		0·0121
B416	Calcium–silico–manganese 14 lb/ton	Before tap	0·42	0·017	0·35	0·32	
		After tap	0·45	0·014	0·63	0·50	
B446	Calcium–silico–manganese 20 lb/ton	Before tap	0·39	0·015	0·45	0·24	0·0148
		After tap	0·38	0·012	0·91	0·47	0·0146

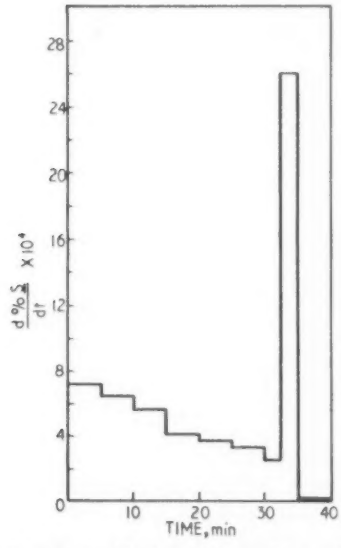
Following the large degree of desulphurization achieved during the experiments in which mixtures of basic materials and magnesium powder were injected under a minimum of slag, it was decided to inject

TABLE V Injections under white reducing slag conditions

Heat no.	Reagent	lb injected/ton	Element increased	% increase	% increase/lb injected/ton
B387	Calcium–silico–magnesium	20	Si	0·39	$0·019_5$
B389		10	Si	0·19	0·019
B390		5	Si	0·15	0·030
B402	Calcium–silicide	10	Si	0·15	0·015
B405		15	Si	0·25	0·017
B409		13	Si	0·26	0·020
B410		4·75	Si	0·14	0·029
B440	Calcium–silico–manganese	10	Si	0·26	0·026
			Mn	0·10	0·010
B444		20	Si	0·33	$0·016_5$
			Mn	0·20	0·010
B445		15	Si	0·32	0·021
			Mn	0·17	0·011
B447		5	Si	0·03	0·006
			Mn	0·06	0·012
B458	Calcium carbide	20	C	0·05	$0·002_5$
B459		30	C	0·20	0·007
B460		20	C	0·09	$0·004_5$
B461		30	C	0·08	0·003



6 *Calcium carbide under reducing slag (30 lb injected per ton)*



7 *Rate of S removal with time during calcium–silico–magnesium treatment (20 lb injected per ton)*

powdered calcium–silico–magnesium, i.e. a 10% magnesium alloy, and burnt lime/magnesium powder mixtures under white reducing slags. The results presented in graphical form in Figs.4 and 5 are typical of those obtained during these injections. Figs.7 and 8 show the rate of change of the sulphur content of the metal bath with time during two of these injections. The increased rate of desulphurization during the injections, as shown in Figs.7 and 8, is the average rate of sulphur removal occurring during the interval from the time the injection was commenced until the time the next sample was taken. In all of these experiments rapid sulphur removal occurred; the actual rate of desulphurization during the injections varying from 0·002% to 0·007% sulphur removed per minute assuming all the sulphur removal occurred during the injection time. Very low sulphur concentrations of the metal were achieved; in one case a final level of 0·002%S was reached. During the injections of calcium–silico–magnesium an increase in the silicon content of the metal occurred; this increase varied from 0·019% to 0·030%/lb of alloy injected/ton of metal treated. When the metal was tapped on to the alloy in the ladle little desulphurization occurred (*see* Table IV) and the silicon content of the metal was increased by only a small amount. The reaction in these ladle experiments was rather violent.

The results obtained may be explained simply as follows (in which the calcium–silico–magnesium is represented by an approximate formula):

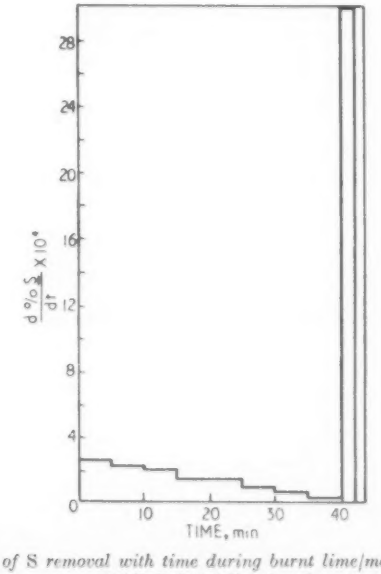
When the powdered alloy is injected into a silicon deoxidized metal bath, the oxygen concentration is reduced further:

$$Ca_2Si_6Mg + 13\underline{O} \rightarrow 2(CaO) + (MgO) + 5(SiO_2) \quad \ldots\ldots(1)$$

As the oxides of calcium and magnesium are much more stable than their sulphides this is the primary

TABLE VI Injections under a minimum of slag

Injectant	Heat no.	Bath deoxidized with	lb injected/ton	Increase in %N	Increase in %N/lb injectant/ton
Calcium carbide	B83	Fe Si	36	0·0118	$0·0003_3$
	B119	Al	30	0·0086	$0·0002_9$
	B141	Al	40	0·0052	$0·0001_3$
Calcium carbide + Mg	B155	Fe Si	24	0·0131	$0·0005_4$
Burnt lime	B135	Al	25	0·0133	$0·0005_3$
Burnt lime + Mg	B162	Fe Si	37	0·0158	$0·0004_3$
Calcium cyanamide	B146	Fe Si	38	0·0229	$0·0006_0$
	B127	Al	28	0·0279	$0·0010_0$
Calcium cyanamide + Mg	B150	Fe Si	36	0·0167	$0·0004_6$
	B172	Fe Si	12	0·0081	$0·0006_8$
Burnt lime + calcium silicide	B192	Fe Si	28	0·0175	$0·0006_3$



8 *Rate of S removal with time during burnt lime/magnesium powder treatment (24 lb CaO/5·9 lb injected per ton)*

TABLE VIII Commercial prices of reagents and carrier gases used

Gas	Consumption per annum, ft³	Cost/ft³, pence
Nitrogen	0–40000	0·684
'Oxygen free' nitrogen	0–12000	1·104
Argon (99·9%)	0–78000	7·000

Injectants	Price, £	Cost/lb, pence
Calcium carbide	46/ton	4·93
Calcium cyanamide	62/ton	6·64
Burnt lime (Grade A about 0·1%S)	5/ton	0·54
Calcium silicide	176/ton (crushed)	18·86
Raremet compound no.5	2·125/5lb	102·0
Magnesium powder	22·4/cwt	48·0
Aluminium powder	19·6/cwt	42·0
Calcium–silico–magnesium	284/ton (crushed)	30·42
Calcium–silico–manganese	200/ton (crushed)	21·43

reaction until the oxygen potential of the bath is very low. When this is the case the desulphurizing reaction (2) occurs rapidly:

$$Ca_2Si_3Mg + 3\underline{S} \rightarrow 2(CaS) + (MgS) + 5\underline{Si} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The sulphur content of the bath is decreased speedily to low levels. Meanwhile, the silicon from the alloy dissolves in this highly deoxidized bath increasing the silicon content of the metal.

When the metal is tapped on to the alloy in the ladle the increase in the oxygen content of the metal which takes place on tapping, together with the atmospheric oxygen, is sufficient to react with the majority of the alloy as in reaction (1). Negligible desulphurization of the metal occurs and the silicon content of the bath is increased by only a small amount.

Rapid sulphur removals have been obtained also by the injection of calcium silicide, calcium carbide, and calcium–silico–manganese. A typical example of the results obtained is given in Fig.6. In the absence of a powerful deoxidizing agent, e.g. magnesium or aluminium, however, these were relatively inefficient desulphurizers at the low sulphur concentrations. This was also true when the metal was tapped on to 20 lb and 15 lb calcium–silico–manganese per ton in the ladle; 0·003%S was removed in each case at initial levels of 0·015% and 0·017%S respectively (*see* Table IV).

The percentage increases in the other elements contained in the metal bath per lb of injectant, when the injections were carried out under white reducing slag conditions, are tabulated in Table V. In all of the injections 'oxygen-free' nitrogen was used as the carrier gas, and an increase in the nitrogen content of the metal was noted (Tables VI and VII). To avoid this, argon should be used as the carrier gas for certain applications.

The increases in the nitrogen content of the metal, per lb of reagent injected, when the injections were carried out under a white reducing slag, were less than those noted for the injections under a minimum of slag. This was primarily due to the use of more efficient dispensing equipment for the injections under the reducing slags, which gave greater powder to gas ratios in the injected streams.

During three of the experiments hydrogen sampling was carried out, and in two of these, when calcium–silico–manganese was injected, the rate of hydrogen pick-up was decreased by the injection. When burnt-lime/magnesium powder was used for the injection the rate of hydrogen pick-up was virtually constant, in spite of the flushing. Particular attention should be paid to dehydrating the burnt lime thoroughly before it is used for injection purposes to reduce the rate of hydrogen pick-up.

TABLE VII Injections under white reducing slag conditions

Injectant	Heat no.	Bath deoxidized with	lb injected/ton	Increase in %N	Increase in %N/lb injectant/ton
Calcium–silico–magnesium	B387	Fe Si	20	0·0114	$0·0005_7$
	B389	Fe Si	10	0·0029	$0·0002_9$
	B390	Fe Si	5	0·0018	$0·0003_6$
Calcium silicide	B402	Fi Se	10	0·0023	$0·0002_3$
	B405	Fi Se	15	0·0016	$0·0001_1$
	B409	Fi Se	13	0·0001	$0·0000_1$
	B410	Fi Se	4·75	0·0004	$0·0000_8$
Calcium–silico–manganese	B440	Fe Si	10	0·0039	$0·0003_9$
	B444	Fe Si	20	0·0030	$0·0001_5$
	B445	Fe Si	15	0·0010	$0·0000_7$
	B447	Fe Si	5	0·0007	$0·0001_4$
Burnt lime + Mg	B450	Fe Si	29·9	0·0009	$0·0000_3$
	B455	Fe Si	18	0·0078	$0·0004_3$
	B457	Fe Si	28	0·0038	$0·0001_4$
Calcium carbide	B458	Fe Si	20	0·0018	$0·0000_9$
	B459	Fe Si	30	0·0052	$0·0001_7$
	B460	Fe Si	20	0·0027	$0·0001_4$
	B461	Fe Si	30	0·0029	$0·0001_0$

The results obtained from the analysis of the slags show a high sulphur partition between slag and metal in most of the experiments.

Costs of injection

Commercial prices of the reagents used in the above experiments together with suitable carrier gases, are shown in Table VIII.

Two examples of the cost of injection are as follows:

(i) 20 lb calcium–silico–magnesium were injected under a white reducing slag at an initial sulphur concentration of 0·015%. The sulphur reduction obtained was 0·008%.

Total cost/ton of steel treated:
using 'oxygen free' nitrogen as the carrier gas 51*s* 6*d*
using argon as the carrier gas 56*s* 2*d*

(ii) 12 lb CaO/6 lb Mg were injected as above at an initial sulphur level of 0·008%. The sulphur reduction obtained was 0·004%.

Total cost/ton of steel treated:
using 'oxygen-free' nitrogen as the carrier gas 25*s* 6*d*
using argon as the carrier gas 30*s* 4*d*.

FUTURE WORK

Further experiments are to be carried out in which burnt lime/magnesium powder mixtures, calcium–silico–magnesium (10% and 15% magnesium alloys), ferro–silico–magnesium, and calcium carbide/calcium fluoride mixtures will be injected under white reducing slag conditions. The rate and degree of desulphurization obtainable with a particular reagent is to be studied at various rates of injection. From the results

obtained it is hoped to find an optimum injection rate for each reagent. During these experiments further hydrogen sampling will be carried out.

CONCLUSIONS

(1) It has been shown that steel can be rapidly desulphurized to low levels by the injection of powdered desulphurizing reagents.

(2) For rapid desulphurization to very low sulphur levels the metal must be strongly deoxidized, either by prior treatment with e.g. aluminium, or by the injectant containing magnesium or aluminium either as an alloy or in the elemental form.

(3) Magnesium powder can be safely dispensed when suitably diluted with powdered materials.

(4) Reproducible sulphur values of about 0·005% can be easily obtained by the injection of calcium carbide or calcium cyanamide into aluminium deoxidized metal baths, also by the injection of mixtures of calcium carbide, calcium cyanamide, or burnt lime with magnesium powder into ferrosilicon deoxidized baths, under the minimum of slag.

(5) The most rapid desulphurization to very low sulphur levels under white reducing slag conditions was achieved when burnt lime/magnesium powder mixtures and calcium–silico–magnesium were used as the injectants. The rate of sulphur removal during these injections varied from 0·002% to 0·007%S/min.

(6) Negligible change in the sulphur concentration of the treated metal was noted on tapping.

(7) In all the experiments 'oxygen-free' nitrogen was used as the carrier gas, resulting in an increased nitrogen content of the metal. Argon should be used to overcome this disadvantage.

(8) The increase in the concentrations of the various elements contained in the metal bath, namely carbon, silicon, and manganese, due to the breakdown of the injected reagents, may preclude the use of certain of these reagents in industrial processes. The burnt lime/magnesium powder mixtures, however, do not appear to have any deleterious side effects.

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Correspondence on the paper

Criterion for peritectic and eutectic reactions*

Mats Hillert, Sc.D.

Mr **A. Prince** (Atomic Energy Division, G.E.C. Ltd) wrote: Dr Hillert has shown that, in the majority of cases, the relative amounts of the α, β, and liquid phases are decisive in differentiating the type of ternary three-phase reaction undergone by an alloy on cooling. The average composition of the alloy then determines for a particular temperature whether the reaction will be eutectic or peritectic.

Hillert's criterion can, of course, be applied to differentiate eutectoid from peritectoid reactions and monotectic from syntectic reactions. His conclusions were, however, formulated in a paper published by Ivanov[1] in 1945.

Ivanov's criterion

Consider an alloy of composition o at a temperature T (Fig. *A*). It consists of liquid l and the two solid solutions α and β. Assume the temperature decreases to $T-dT$ and that the phase compositions change to α', β', and l'.

If the change in temperature is sufficiently small the processes which occur can be divided into two distinct parts:

(i) a change in the composition of the phases
(ii) a change in their amounts.

Ivanov considers the change in composition first. Liquid l is in equilibrium with solid of composition a at temperature T. With a fall in temperature dT and assuming no change in the amount of the phases liquid l'_1 will now be in equilibrium with solid of composition c. This is so because of the following relations:

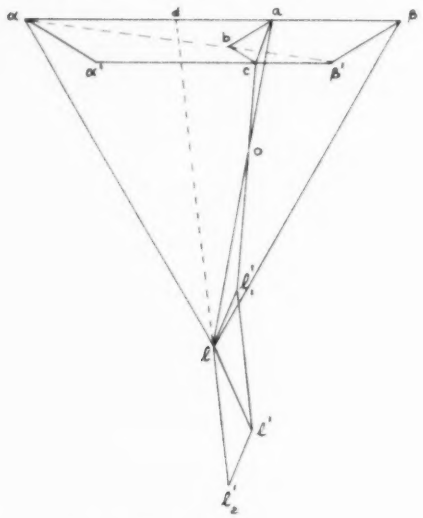
$$\frac{m\alpha}{m\beta} = \frac{\alpha\beta}{\alpha a} = \frac{b_l\beta'}{\alpha b} = \frac{c\beta'}{\alpha' c} = \frac{m\alpha'}{m\beta'}$$

it being understood that ab is parallel to $\beta\beta'$ and bc parallel to $\alpha\alpha'$. Also

$$\frac{m\alpha + m\beta}{m_1} = \frac{lo}{oa} = \frac{l'_1 o}{oc}$$

it being understood that triangles oac and oll'_1 are similar and ll'_1 is parallel to ac.

JISI, 1958, **189,** 224–226.



A *Illustration of Ivanov's criterion*

B *Application of Ivanov's criterion to the demarcation of reaction regions*

According to the phase diagram the liquid composition at a temperature $T-dT$ is l'. Ivanov states that this is a result of two processes of which only the first has been considered in arriving at liquid l'_1. With a change in composition only the liquid moves to point l'_1. A change in the amount of the phases, corresponding to the separation of solid, displaces the liquid composition to l'_2. The resultant change in liquid composition is from l to l'.

This now leads to a statement of Ivanov's criterion: *The composition of the solid phases formed at temperature* T *is established by the point where the tie line* $\alpha\beta$ *or its extension meets the extrapolation of the line* ll'_2.

In Fig.*A* the point of intersection is d. As on the old criterion for eutectic or peritectic reactions if the point of intersection is within the tieline $\alpha\beta$ the reaction is eutectic ($l\rightarrow\alpha+\beta$); if it is on the right-hand extrapolation of the $\alpha\beta$ tieline the reaction is peritectic ($l+\alpha\rightarrow\beta$) and on the left-hand extrapolation peritectic also ($l+\beta\rightarrow\alpha$).

Ivanov also points out that the direction ll'_2 and therefore the type of reaction is dependent on the average composition of the alloy. The exceptions to this rule are noted as follows:

(i) when the composition of the α and β phases does not change with fall in temperature, i.e. when α and β are pure components
(ii) when the α, β, and liquid curves are mutually parallel at the temperature under consideration
(iii) at the beginning of crystallization of alloys whose average composition is on the liquid curve
(iv) for alloys whose composition is on the line *la* when the line *ac* is parallel to the tangent to the liquid curve at point l. In this case l, l', l'_1, and l'_2 lie on one straight line.

Comparison of Hillert and Ivanov criteria

The two systems discussed by Hillert can be used to compare the two criteria.

(1) *Two binaries show complete miscibility and the third is eutectic*

Using the configuration of phases in Fig.*B*, Hillert's method leads to a demarcation of three reaction regions. A peritectic ($l+\beta\rightarrow\alpha$) isolates the α corner; a peritectic ($l+\alpha\rightarrow\beta$) isolates the β corner and the remainder of the three-phase triangle is eutectic. For the system shown the equation of the boundary lines are:

$l+\beta\rightarrow\alpha$/eutectic $\quad 15n_\beta+6n_l=500$

$l+\alpha\rightarrow\beta$/eutectic $\quad 15n_\alpha+14n_l=500.$

The use of Ivanov's criterion to demarcate the reaction regions is illustrated in Fig.*B*. For simplicity only the construction for the boundary line isolating the β corner is given. The $l+\alpha\rightarrow\beta$/eutectic boundary line is determined as follows:

(i) draw a number of lines, *ab* and *ac*, parallel to $\beta\beta'$ and $\alpha\alpha'$ respectively. Join *a* to *c*
(ii) the demarcation of the peritectic from the eutectic region coincides with the concurrence of l'_2l with the $l\beta$ side of triangle $\alpha\beta l$. Since $l'l'_1$ is parallel to l'_2l draw a line through l' parallel to the $l\beta$ side of triangle $\alpha\beta l$
(iii) draw a line through l parallel to *ab*. The intersection of this line with the line through l' parallel to $l\beta$ gives the location of l'_1
(iv) join l'_1 to *c*. The point of intersection of this line with *la* is a point on the boundary line.

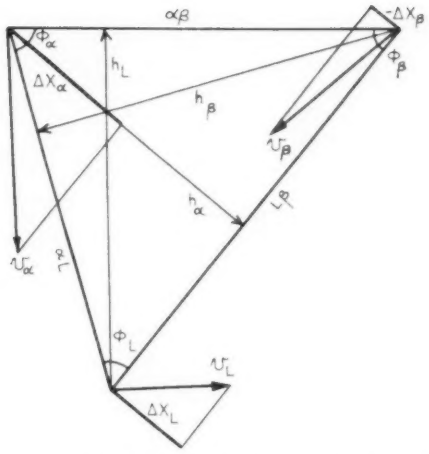
The boundary line constructed from Ivanov's criterion agrees well with that calculated from Hillert's criterion. Discrepancies between the two are due to errors in construction on the scale adopted for Fig.*B*. The advantage in using Ivanov's criterion is that a geometric method provides an easier solution in the case of non-equilateral three-phase triangles.

Alloys whose compositions lie on the boundary lines between reaction regions undergo neither peritectic nor eutectic reaction at the temperature T. In the case of the $l+\alpha\rightarrow\beta$/eutectic line alloys undergo a two-phase reaction $l\rightarrow\beta$ at T. For the $l+\beta\rightarrow\alpha$/eutectic boundary line alloys undergo the $l\rightarrow\alpha$ reaction at T.

(2) *One binary is peritectic, one eutectic and the third shows complete miscibility*

Again the application of either criterion leads to the same conclusions. Ivanov noted that the transition from peritectic ($l+\beta\rightarrow\alpha$) to eutectic reaction in this system is accomplished at different temperatures for different alloys. The assumption that the transition occurs at a particular temperature is incorrect.

Applying Ivanov's criterion (or Hillert's) it can be shown that the transition from peritectic to eutectic reaction begins at the α apex of the $\alpha\beta l$ triangle when the tangent to the $\alpha\alpha$ curve at the α apex becomes parallel to the tie line αl (corresponding to temperature T_2 in Fig.3 of Hillert's paper). With fall in temperature the eutectic region grows and sweeps round from the α apex towards the β and l apices. At T_3 the tangent to the ll curve at the l apex becomes parallel to the



C *Other quantities to be used in deriving graphical representation of the mathematical criterion*

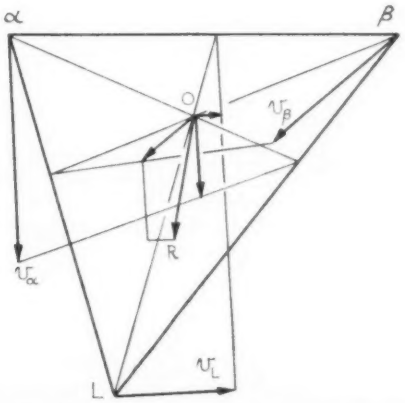
tieline αl. Corresponding to this the boundary between the peritectic and eutectic region passes point l. Finally, at T_4 the boundary sweeps past point β to convert the entire triangle into a eutectic region. At this temperature the tangent to the $\beta\beta$ curve at the β apex becomes parallel to the tieline αl.

In general, as Ivanov states, the boundary between the peritectic and the eutectic regions passes through the apices of the three-phase triangles in the same order in which the tangents to the curves $\alpha\alpha$, ll, and $\beta\beta$ at the apices α, l, and β respectively become parallel to the αl tieline.

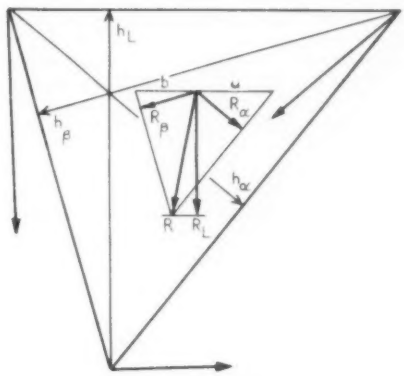
AUTHOR'S REPLY

Dr **Mats Hillert** wrote: It has been brought to my attention that the problem of predicting from the phase diagram whether a reaction is peritectic or eutectic was tackled by Schramm[2] in 1935 and by Schramm and Luckert[3] in 1937. They were not only interested in the amount of a phase, however, but also in its total content of a certain element. On account of this more general approach their mathematical treatment is quite complex. On the other hand, this approach may resolve the problem whether the amount of a phase should be defined by its weight or number of moles mentioned in the introduction of the paper under discussion. What one really likes to know is, of course, whether a certain element will enter or leave the phase as the reaction proceeds.

Mr Prince draws attention to the work of Ivanov, who has found a graphical criterion, and in two particular cases, Mr



D *Graphical derivation of vector R from three other vectors*



E *Vector R projected on three directions*

Prince compares this with the mathematically formulated criterion in the paper under discussion. It seems that the comparison would be simplified if the mathematical criterion is also represented graphically, which can be done in the following way.

The mathematical expression derived in the paper can be written as

$$\frac{\Delta n_\alpha}{\Sigma n} \cdot h_\alpha = R_\alpha$$

where

$$R_\alpha = \frac{n_\alpha}{\Sigma n} \cdot \Delta x_\alpha + \frac{n_\beta}{\Sigma n} \cdot \Delta x_\beta + \frac{n_L}{\Sigma n} \cdot \Delta x_L.$$

Figure *C* defines the other quantities to be used. The arrows v_α, v_β, and v_L represent the direction and magnitude of the compositional changes and Δx_α, Δx_β, and Δx_L are the projections of these arrows on the prescribed direction, which is that of h_α. The quantity R_α can thus be obtained as the projection of a vector R on the prescribed direction. One has

$$\vec{R} = \frac{n_\alpha}{\Sigma n} \cdot \vec{v_\alpha} + \frac{n_\beta}{\Sigma n} \cdot \vec{v_\beta} + \frac{n_L}{\Sigma n} \cdot \vec{v_L}.$$

Figure *D* demonstrates how this vector is found graphically as the sum of three vectors. The mean composition, which defines n_α, n_β, and n_L is represented by the point O. The magnitude of all the three changes Δn_α, Δn_β, and Δn_L may now be obtained by evaluating R_α, R_β, and R_L as the projections of the vector R on the three prescribed directions, as demonstrated in Fig.*E*. If one is only interested in the sign of Δn_α, Δn_β, and Δn_L it is enough to examine how the vector R is directed compared with h_α, h_β, and h_L. In this particular case R points away from the α and β corners but towards the L corner, indicating that the amounts of α and β are increasing, whereas the amount of L is decreasing. If one is interested in the ratio of the changes for two of the three phases, e.g. $\Delta n_\alpha/\Delta n_\beta$, one should not compare R_α and R_β but rather R_α/h_α and R_β/h_β. The ratio is easily obtained as a/b in Fig.*E* since

$$a = R_\alpha/\sin\phi_\beta = \frac{\Delta n_\alpha}{\Sigma n} \cdot h_\alpha / \frac{h_\alpha}{\alpha\beta} = \alpha\beta \cdot \frac{\Delta n_\alpha}{\Sigma n}$$

and

$$b = R_\beta/\sin\phi_\alpha = \frac{\Delta n_\beta}{\Sigma n} \cdot h_\beta / \frac{h_\beta}{\alpha\beta} = \alpha\beta \cdot \frac{\Delta n_\beta}{\Sigma n}.$$

It is easily shown that the line l–l'_2 in Ivanov's treatment, if considered as a vector, is related to our vector R by the relation

$$\vec{R_{ll'_2}} = \frac{n_\alpha}{n_L} \cdot \vec{v_\alpha} + \frac{n_\beta}{n_L} \cdot \vec{v_\beta} + \vec{v_L} = \frac{\Sigma n}{n_L} \cdot \vec{R}.$$

These two vectors thus have the same direction and a/b in our treatment is identical to $\alpha d/d\beta$ in Ivanov's. As a consequence, the graphical criterion found by Ivanov and the mathematical criterion, derived in the paper under discussion, must always give identical answers whether a certain reaction is peritectic or eutectic, which was, indeed, found by Mr Prince in the two cases examined by him.

If one prefers a graphical criterion it seems a greater advantage to use the method demonstrated in Figs. *D* and *E* than Ivanov's original method for two reasons. First, it is easier to find R than $R_{W'_2}$. Second, R yields quantitative information about all three phases whereas Ivanov's criterion only yields information about the *relative* change of *two* of the three phases. It should thus be noticed that the extension of the line l–l'_2 in Ivanov's criterion intersects the tieline $\alpha\beta$ between α and β if the amounts of α and β are both increasing or both decreasing.

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STAL *in English*

The first 12 issues of *Stal in English* have been favourably received by the iron and steel industry in the UK and abroad. Number 1 of the 1960 series has now been published and subsequent issues will appear at about three-weekly intervals. Principal contents of nos.2 and 3 are given below. Full details of subscriptions to *Stal in English* are available from the Secretary of The Iron and Steel Institute.

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Improved blast-furnace gas cleaning

S. A. Lewitt, B.Sc., M.I.E.E.

SYNOPSIS

This paper describes the investigations into a gas-cleaning plant serving two 27-ft blast-furnaces. The three-stage cleaning plant was unable to clean down to figures acceptable for underfiring coke-ovens and caused serious deposits in the power station boiler plant and gas mains. Alterations were made to the electro-precipitators and to the internals of the washers. As a result the final dust burden is now less than $\frac{1}{10}$ of the previous average figures and is consistently 0·001–0·0015 gr/std. ft³.

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INTRODUCTION

THE IRONMAKING PLANT at Shotton consists of two 27-ft blast-furnaces installed in 1953 and 1955, each with conventional primary and secondary dust catchers. Beyond the dust catchers the gas is brought to a common dust leg, followed by two 18-ft dia. packed scrubbing-towers and three 28-ft dia. irrigated-tube type electro-precipitators of US design. The blast-furnace gas is used for the blast-furnace stoves, underfiring the coke-oven batteries, and the balance mainly for water-tube boilers in a central power station.

The plant specification promised the following dust burdens:

Leaving washers	0·25 gr/ft³ with 90000 ft³/min throughput
Leaving precipitators	0·005 gr/ft³ with 60000 ft³/min throughput.

With one precipitator out of service the dust burden was expected to be 0·0175 gr/ft³.

Early experience with the plant showed that these figures could be obtained only very occasionally, the averages being very much higher. Even week-to-week averages changed by as much as 2:1, the range of figures experienced being as follows:

Inlet to washers	1·0–7·0 gr/ft³
Outlet from washers	0·2–0·7 gr/ft³
Outlet from precipitators	0·005–0·04 gr/ft³.

The reasons for this wide range were investigated over a lengthy period; everything that went into the furnace, and everything that came out, was studied and analysed, and attempts were made to relate variables with the variations in gas cleanliness. Some of these variables, particularly moisture content of the blast, water additions to the top of the furnace, ore/coke ratios, and the temperature of the iron, seemed to some extent to move in sympathy with the gas cleanliness. Figure 1 shows an interesting graph of dust burden plotted against moisture content in the blast over a period of about eight days. But as most of these factors were dictated by the day-to-day needs of blast-furnace operations, they could not be looked upon as really helpful to the problem.

After about a year of operation it was evident that there was no simple solution, and all the gas consumers were in serious trouble. It is common practice in coke-oven operations not to accept blast-furnace gas at a higher figure than 0·008 gr/ft³, owing to fouling of the regenerators. In our case gas was acceptable to the coke-ovens for such short periods that it was almost worthless. The power station was able to burn the gas but was in constant trouble: burners and gas valves built up with deposit several inches thick within a matter of weeks; air heaters and economizers blocked so quickly that it was impossible to keep boilers working at full output for any length of time. Down-time for cleaning was serious. Gas mains built up at bends and several times needed a complete shutdown for cleaning. The precipitators themselves needed cleaning every six weeks.

PRECIPITATORS

Work was first concentrated on the precipitators, as it was felt that these might yield quickest results. Tests

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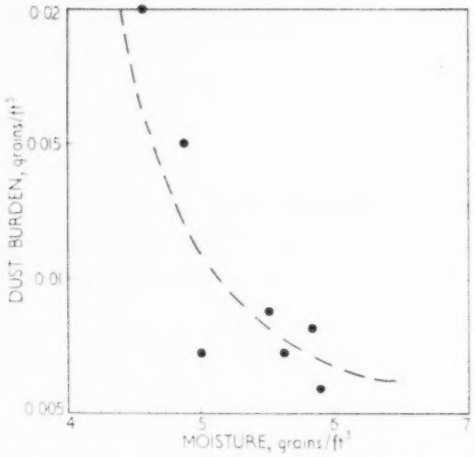


1 *Dust burden/moisture in blast over an 8-day period*

were taken daily over many months, and a Kapnograph recorder was used. A series of tests taken in September 1956, is shown in Table I; the average precipitator efficiency was about 93%.

Dust samples were taken from each cleaning stage and the analysis of these is given in Table II. This shows how the alkalis increased until they reached around 30% in the clean gas. Also they appeared to be easily deposited in the power station burners where they had increased to 50%. The coke used had about 0·35% alkali and seemed to be volatilized inside the furnaces, forming a fume so fine that both washers and precipitators failed to remove it, thus causing the increase through the cleaning plant.

Possibly one of the main causes of poor performance was the capacity of the installed high-voltage sets. These sets give half-wave rectified current to each half of the precipitator and the peak voltage was measured as 66 kV. Tests were made using two rectifiers with one precipitator and full wave supply, but this did not give any marked improvement. Using higher voltage plant was considered but was estimated to cost at least £50000, without any certainty of solving the problem.

The distribution of gas through the precipitator tubes was thought to be a contributory factor. The tubes are 15 ft long and 12 in. dia. and the nominal gas

TABLE I Dust burden of blast-furnace gas September 1956

Date, September 1956	Precipitator outlet gr/std. ft³
1	0·014
2	0·007
3	0·01, 0·008
4	0·019, 0·027
5	0·021
6	0·011, 0·01
7	0·022
17	0·017
24	0·006
26	0·007

flow through each tube is 230 ft³/min corresponding to a velocity of 5 ft/s. The pressure drop across the tube bank is, therefore, only about 0·003 in. wg. Calculation showed that there were quite high gas velocities at the entry and exit connexion to the precipitator, particularly when the outsides of the tubes were dirty, and hence the attendant velocity head could easily affect distribution with such a small pressure drop across the actual tube bank. The problem was how to measure the gas flow through the tubes without disturbing the operation of the plant. The first attempt was to make a pitot tube survey above the tubes but this was inconclusive. Plant was therefore installed to blow air through one precipitator, and two axial flow fans giving a total of 60000 ft³/min against 6 in. wg were led into the gas inlets.

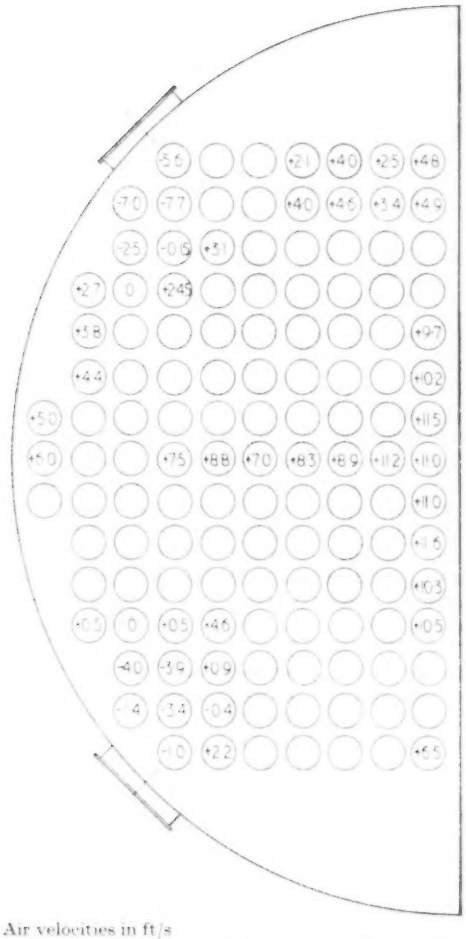
The tests showed a distribution as in Fig.2. Some 28% of the tubes were carrying more than 150% of average flow, and 10% of the tubes were actually carrying a reverse gas flow. Correction of this maldistribution by using baffles at both inlet and outlet was made by trial and error. Finally, when this proved ineffective, a complete ring with four extra inlets was added to the gas inlet, as shown in Fig.3. The final gas distribution, the best which could be achieved in the limited time available, is shown in Fig.4.

The three precipitators were modified in this way and a further series of dust tests made to find the improvement, with the results summarized in Table III. The outlet from the precipitators was now mainly within the range 0·002–0·011 gr/ft³ and average efficiency very near to 98%.

Although the precipitators had been brought up to their specified efficiency, the outlet burden was still occasionally reaching 0·020 gr/ft³ in sympathy with a washer outlet of 0·6–0·7 gr/ft³. No definite reason

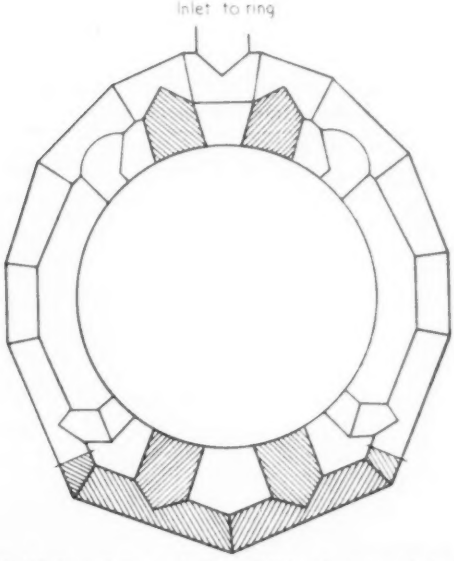
TABLE II Dust samples from gas cleaning plant

Sample	1 Deposit from primary dust catcher	2 Deposit from secondary dust catcher	3 Deposit from washers	4 Dust in gas leaving washers	5 Deposit from precipitator	6 Dust in gas leaving precipitator	7 Deposit in power station burners
Insol.	8·50	11·60	9·40	13·68	22·60	11·44	
Fe2O3	75·43	53·00	61·30	14·40	19·30	8·64	3·52
Al2O3	1·80	1·55	4·35	6·91	15·58	6·70	
MnO	0·62	0·60	0·63	2·16	1·10	1·49	
CaO	1·60	2·40	3·56	6·36	7·12	4·68	2·80
MgO	0·80	1·09	1·67	8·04	9·90	9·28	3·04
P	0·24	0·20	0·41	0·54	0·71	0·57	0·14
S	...	...	0·41	1·89	1·33	1·37	0·36
Cl	trace	trace	nil	1·32	0·20	3·44	29·22
Zn	nil	nil	nil	1·20	0·90	1·20	0·70
Na2O	0·28	0·32	0·25	9·25	1·55	9·75	5·80
K2O	0·56	0·92	0·55	20·90	2·70	22·40	36·15
Loss on ignition	5·90	23·50	15·65	...	15·95	...	9·06

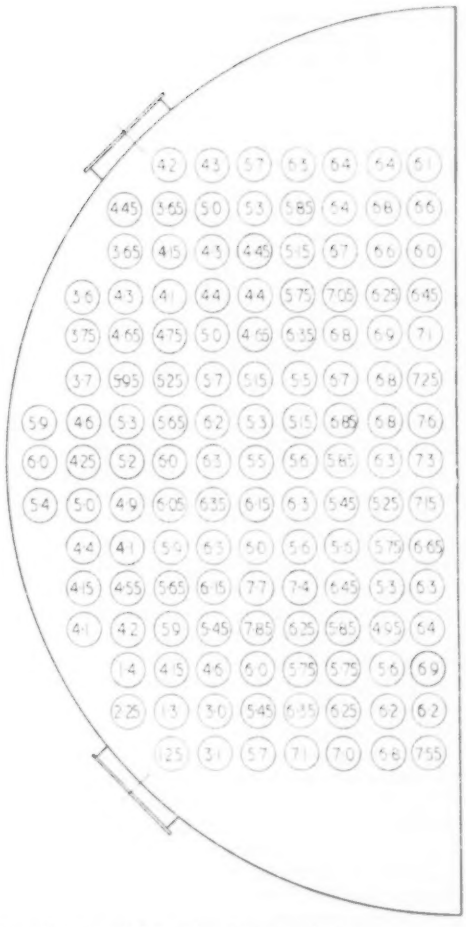


Air velocities in ft/s

2 *Distribution through precipitator tubes before modification*



3 *Modified precipitator showing additional section of ring and four new inlets*



Air velocities in ft/s (all values positive)

4 *Distribution through precipitator tubes after modification*

could be found for this, but it was generally considered to be associated with combustion conditions in the furnaces.

WASHERS

As the washers were still not capable of cleaning consistently to the figure of 0·25 gr/ft³, the washer efficiency obviously had to be improved. Two methods were considered: first, using a high-pressure drop

TABLE III Dust burden of gas after modification to precipitators

Date, March 1958	Precipitator outlet, gr/std. ft³
3	0·01, 0·005
5	0·005
6	0·002
8	0·008
10	0·008, 0·010
11	0·008, 0·004
13	0·003
18	0·007
19	0·011, 0·020
20	0·007
24	0·010
25	0·006
31	0·005

TABLE IV Pilot scrubber tests with four plate stages: gas extraction from washer inlet, pressure drop across four stages 12 in. wg

Test no.	Date, February 1957	Gas inlet temp., °F	Dust loading, gr/std. ft³ Inlet	Outlet	Removal efficiency, %
1	27	290	7·0	0·1	98·5
2	27	280	5·32	0·098	98·2
3	27	290	2·93	0·077	97·4
4	27	285	7·78	0·057	99·2
5	27	320	6·08	0·12	98·1
6	28	315	2·87	0·135	95·3
7	28	295	3·49	0·106	97
8	28	265	2·29	0·083	96·4

TABLE V Pilot scrubber tests with two plate stages: gas extraction from mid-point of washer, pressure drop across two stages 6 in. wg

Test no.*	Gas inlet temp., °F	Dust loading, gr/std. ft³ Inlet	Outlet	Simultaneous tests on existing washer dust loading, gr/ft³ Inlet	Outlet	Efficiency, %
1	61	0·865	0·216	2·213	0·303	86·3
2	61	0·772	0·197	1·89	0·436	76·9
3	61	0·547	0·137	...	...	...
4	61	0·623	0·208	...	...	...
5	61	0·60	0·22	...	...	...
6	61	0·509	0·183	...	...	...

* All tests carried out on 31 January 1957.

venturi scrubber, possibly with the existing washers as water separators; and second, modifying the internals of the washers.

It seemed, from published data, that the venturi scrubber would deal with the problem, but would involve a major reconstruction of the gas mains between the secondary dust catchers and the washers.

The possibility of altering the washer internals was investigated, and it was decided to instal a Peabody pilot washer to try various combinations of slot plates and impingement plates, taking the gas from different stages of the washer. Tests were made for a period of three months in early 1957 and a summary of these tests is given in Tables IV–VI. Every effort was made to reproduce the conditions in the washers so that the results from the pilot plant could be taken as a reliable guide. No build-up of dust on the plates was found, even after a lengthy run.

These tests clearly showed that the only method of achieving the required results was to use a high pressure drop of 10–15 in. wg. The high pressure achieves intimate mixing of gas and water, and effective wetting and agglomeration of the dust. An interesting graph was drawn (Fig.5) showing how the outlet dust burden varied with pressure drop. Our blast-furnace management felt that an extra top gas pressure of 12 in. wg would be acceptable; top gas pressure was then around 45 in. wg and this would be increased to 56–60 in. wg.

After these tests it was decided that an alteration, based on a pressure drop across the two stages of 12 in. wg, should be made to the two washers. The two top 3-ft tile banks would be removed and replaced by a slot plate stage and impingement stage. A section through the washer as it would appear after modification is shown in Fig.6.

A reline of one furnace was made early in 1958 and advantage was taken of this to carry out the modifications to both washers. Except for supports and water troughs, stainless steel was used throughout for both stages; the slots were made adjustable between $\frac{1}{2}$ and $\frac{3}{4}$ in., to allow for an increased gas throughput in the future, but with the stage pressure drop held at about 12 in. wg.

After conversion the first tests gave outlet loadings of 0·04–0·08 gr/ft³ which seemed very promising. This continued for three or four weeks until the relined furnace came into operation, when after a few days operation some rather alarming troubles developed.

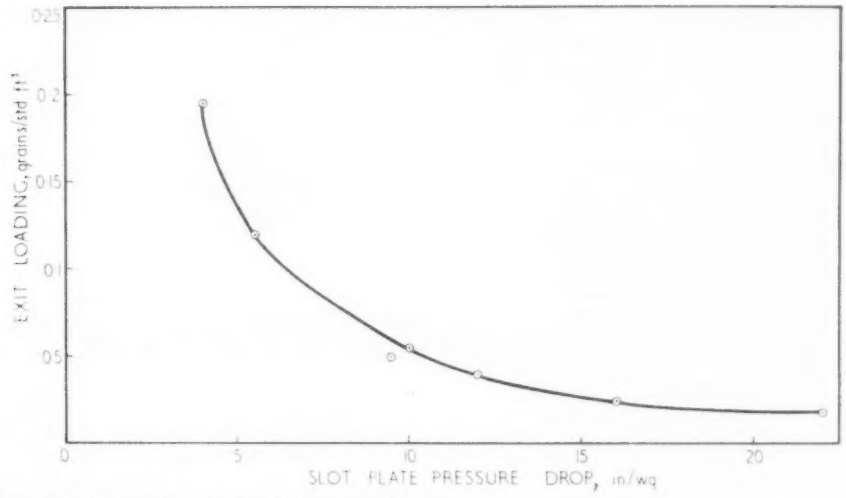
The pressure drop across the impingement stage of no.2 washer increased rapidly and soon the washer had to be opened for inspection. Almost all the $\frac{1}{16}$-in. holes were found blocked with a hard material (Fig.7) the analysis of which is given in Table VII. The plates were scraped and replaced but after a few more days operation the same condition recurred. As no.1 washer was similarly affected, the whole impingement stage was temporarily abandoned. Four complete plates measuring 2 ft × 5 ft 6 in. were removed from opposite sides of each washer, and to prevent excessive carry-over of water from the slots below, entrainment canopies were placed over the holes. With this condition the plant operated normally but it was naturally expected that some worsening of the gas cleanliness would be found. A further series of dust tests was made and this gave 0·1–0·15 gr/ft³.

After two weeks pressure drops were again becoming serious and these were found across the slot plates of both washers. When examined, the slots were found to be 50–70% closed with a hard material similar to that removed from the impingement plates. The analysis is given in Table VII.

This fouling of the slot plates after a relatively short time was alarming, because access to the slots was difficult and cleaning a slow process, and all down-time on a washer involved banking a furnace. Attempts to remedy this situation were made in two directions: (*a*) to find a material, perhaps a very smooth material, on which the dust could not stick (different sizes of slots was another possibility) and (*b*) to make the water sprays more effective and so prevent the dust from sticking.

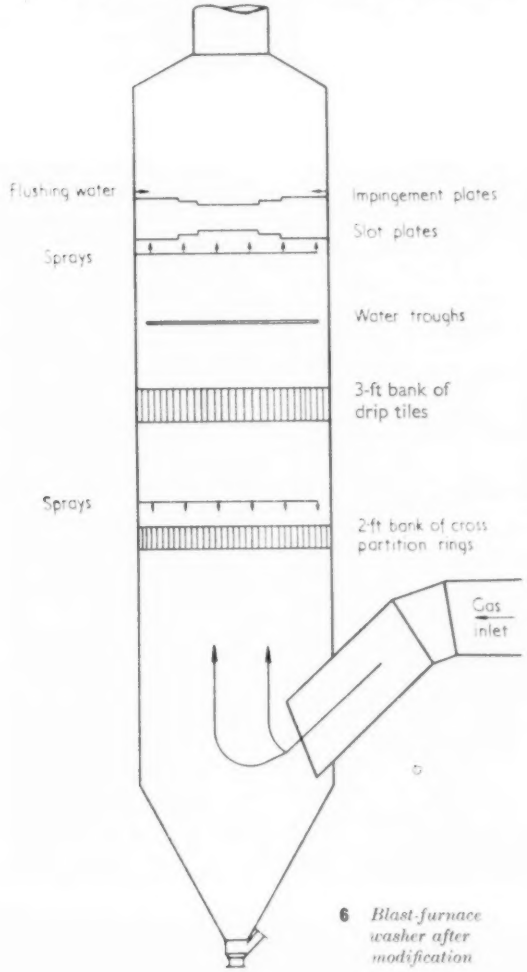
TABLE VI Pilot scrubber tests with two plate stages: gas extraction from mid-point of washer

Test no.	Date, February 1957	Slot plate pressure drop, in. wg.	Dust loadings, gr/std. ft³ Inlet	Outlet	Existing washer loadings, gr/std.ft³ Inlet	Outlet
1	13	13	0·281	0·059	1·9	0·275
2	13	17	0·291	0·036	...	0·24
3	13	17	0·346	0·066	...	0·336
4	14	17	0·394	0·019	2·71	...
5	14	17	0·351	0·022	2·31	0·345
6	14	23	0·389	0·024	1·74	...
7	14	23	0·30	0·010	1·49	0·244
8	21	11	0·476	0·059	2·17	0·489
9	21	11	0·497	0·058	2·19	0·421
10	21	11	0·505	0·051	2·23	0·469
11	21	6	0·456	0·075	2·53	0·419
12	21	6	0·515	0·11	2·02	0·461
13	21	6	0·496	0·125	2·1	0·453
14	22	9	0·94	0·052	1·95	0·544
15	22	9	0·585	0·078	2·24	0·604
16	22	9	0·70	0·128	2·33	0·313
17	27	13	...	0·039	2·58	0·268
18	27	13	0·318	0·038	4·01	0·302
19	27	13	0·365	0·043	3·79	0·303
20	27	10·5	0·47	0·049	2·94	0·359
21	27	10·5	0·378	0·051	2·59	0·365
22	27	10·5	0·367	0·048	2·03	0·337



5 *Pilot scrubber outlet dust loading and slot plate pressure drop*

The possible materials included teak, rubber coating, and plastic (Sakaphen) coating. Guidance on materials was given by Rice,* where he refers to the use of rubber as a coating material: 'Deposits of blast-furnace gas dust with their familiar hydraulic setting tendency do not cling as tenaciously to rubber as they do to some other surfaces such as metal. But a very important reason for using rubber is the ease of completely wetting it with comparatively little volume of water.'



6 *Blast-furnace washer after modification*

Slot plates were made up using all the above materials, and also different sizes of slots and chimneys. Water sprays using flat V jets, each to give effective coverage of each slot, were tried simultaneously below a number of slots.

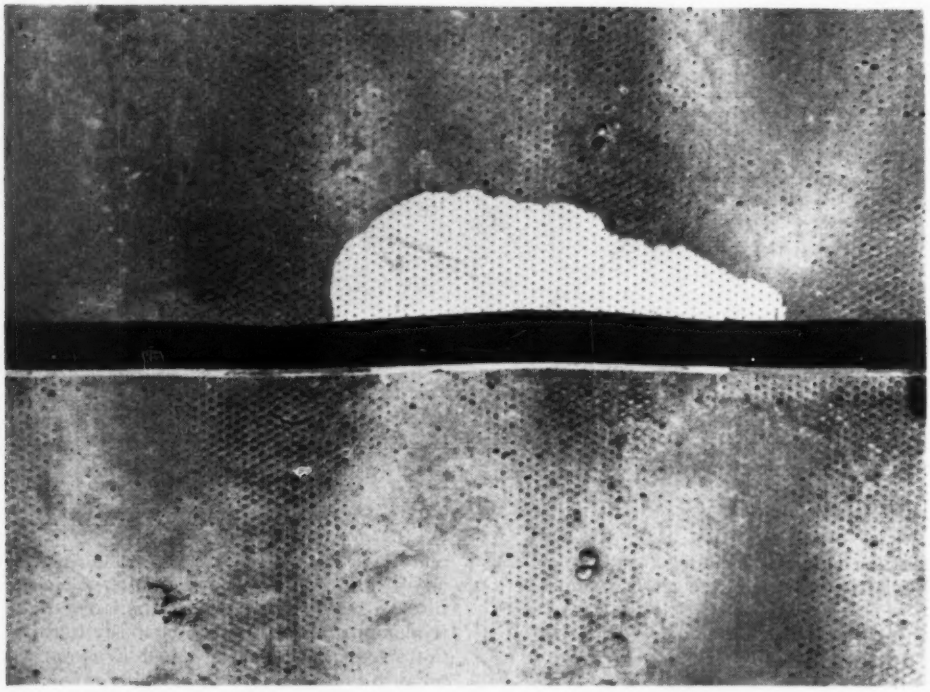
These trials were made in October 1958, and an examination made after 27 days. Figures 8*a–d* show the results of the different materials, and of the slots with the extra water sprays. It was concluded from this that material has little control over the adhesion of the dust, and in fact the materials with the smoothest surface, i.e. rubber and plastic coating, were worse than the bare metal. The water sprays seemed by far the most promising, so a complete set of V sprays was prepared and installed in both washers. Figure 9 shows how the pressure drop benefited from the spray modifications, until finally the water sprays were completely effective in preventing build-up, and the plant settled down to steady operation, as to the present day.

CONCLUSIONS

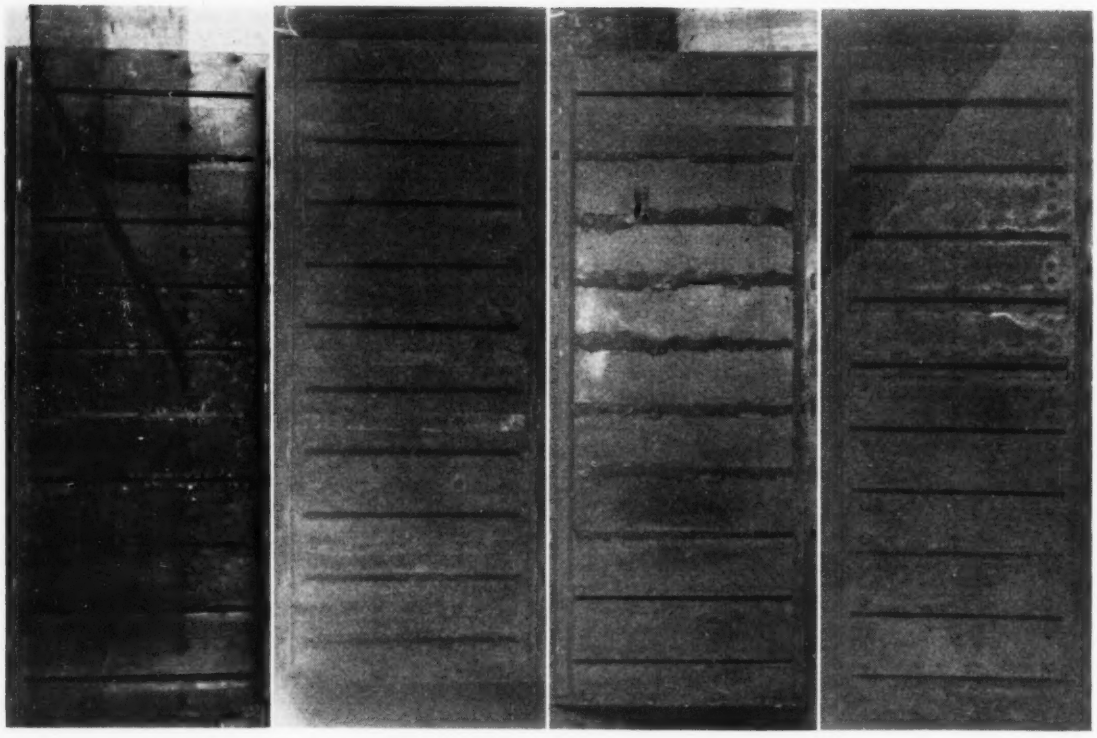
Gas leaving the washers now averages 0·08–0·15 gr/ft³, and leaving the precipitators 0·0005–0·0015 with an average of 0·001 gr/ft³. The progress can be summarized as:

	Washer outlet gr/ft³	Precipitator outlet, gr/ft³	Average precipitator efficiency
Original working	0·2–0·7	0·005–0·04	92%
After precipitator alterations	0·2–0·7	0·005–0·014	98%
After washer alterations	0·08–0·15	0·0005–0·0015	99%

* D. R. Rice: *Iron Steel Eng.*, 1942, **19**, 66–89.



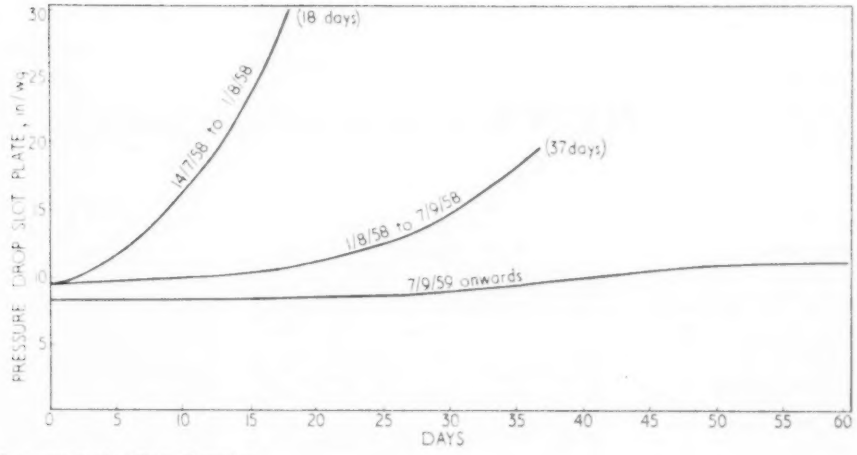
7 *Impingement plate with* $\frac{1}{16}$*-in. holes*



a b c d

(*a*) Plastic (Sakaphen)-coated slots (*b*) Rubber-coated slots (*c*) Wooden slots (*d*) Slots with extra water sprays

8 *Underside view of slot plates*



9 *Pressure drop across slot plate of washer*

The improvement to the washers also improved the efficiency of the precipitators. The likely explanation of this is that the high-pressure drop slot stage in the washer effectively agglomerates the fume, although not actually removing all of it, and thereby presents a gas to the precipitators which they can deal with more easily. Consistent results at these levels have now been obtained over the last nine months and an occasional inspection of the slot plates shows that build-up is negligible and can be dealt with easily during normal down-time for cleaning of sprays etc.

Results in the power station boilers show a remarkable improvement. Burners and valves which previously built up within a few weeks are now almost free from deposit; and the gas is consistently in use for underfiring the coke-ovens.

Further work is currently in hand using experimental plates with a smaller number of $\frac{3}{16}$-in. holes, as it is felt that if the impingement plates can be restored to use, the final gas cleanliness can be still further improved. Another factor is that dust removed in the washers means less deposit at the inlets to the precipitators and hence less cleaning. Impingement plates using the $\frac{3}{16}$-in. holes have been in operation for 4–5 months without showing any deposit, and the next step will be to change all the plates to this size of hole, and restore the complete stage.

TABLE VII Deposits on plates in gas washers

	Impingement plates, %	Slot plates, %
Ferric oxide	8·00	21
Alumina	2·40	2
Zinc oxide	15·00	24
Lime	24·60	0
Magnesium oxide	2·04	trace
Sodium oxide	0·20	0·3
Potassium oxide	7·20	15·4
Sulphur	1·25	1·5

ACKNOWLEDGMENTS

Something like three years was spent in finding a solution to this particularly stubborn problem, and the first year produced nothing but disappointments for the efforts put into it.

The writer wishes to thank Dr R. F. Heinrich of Messrs Simon Carves Ltd, Mr F. S. Smith of Messrs Peabody Ltd, and his colleagues Mr R. W. Davis, Mr J. B. Edwards, and Mr E. Williams, without whose help these notes could not have been written.

NEWS | *Announcements and News of Science and Industry*

THE IRON AND STEEL INSTITUTE

Honours for Italian iron and steelmakers

The following elections have been made in connexion with the Special Meeting in Italy.

Honorary member
Professore F. de CARLI, President of the Associazione Italiana di Metallurgia, has been elected an Honorary Member.

Honorary Vice-Presidents
Dott. Ing. G. FALCK, President of the Società Acciaierie e Ferriere Lombarde Falck, and Professore E. MANUELLI, Managing Director of Finsider, Rome, have been elected Honorary Vice-Presidents.

Other changes on Council

Elected Honorary Vice-Presidents
Mr N. H. ROLLASON (Vice-President), Managing Director of John Summers and Sons Ltd.
Dr J. W. JENKIN (Member of Council), member of the governing body of the Research and Development Division of Tube Investments Ltd.

NEWS OF MEMBERS

Mr **R. F. Cobbett** has joined Aminoil Inc.

Mr **M. H. Farmer** is now at the Corning Glass Works, Corning, N.Y.

Mr **Russell Franks** has retired from the post of manager of the marketing research division of the Union Carbide Metals Company. He continues to serve the company as a consultant.

Mr **R. N. H. Gardner** is now Midlands Area Manager (Technical Sales) of McKechnie Bros. Ltd.

Mr **E. J. Hancock** has been appointed Sales director of Savin (Tools) Ltd.

Dr **N. P. Inglis** has been elected to the council of The British Non-Ferrous Metals Research Association.

Dr **B. R. Nijhawan** has been elected president of The Institute of Indian Foundrymen and vice-chairman of the Structural and Metals Division Council of The Indian Standards Institution.

Mr **F. W. Percival** has been appointed foundry superintendent of the Ivor Works, Dowlais, of Guest Keen Iron and Steel Co. Ltd.

Mr **H.H. Utley** has been appointed managing director of Davy and United Roll Foundry Ltd.

Mr **I. G. Walker** has been appointed head of the assembly group laboratory, Ford Motor Co. Ltd.

Mr **D. J. Willetts** has joined Crittall-Luxfer Ltd.

Obituary

William Johnstone (*elected* 1948) of Glasgow, on 23 December 1959.

POWDER METALLURGY JOINT GROUP

Next meeting of Group

The next meeting of the Powder Metallurgy Joint Group of The Iron and Steel Institute and The Institute of Metals will be held at Church House, Great Smith Street, London SW1, on Thursday and Friday, 15 and 16 December 1960.

One day will be devoted to a Symposium on 'The practical aspects of pressing metal powders', papers contributed to which will be printed, in advance of the meeting, in *Powder Metallurgy*, the half-yearly periodical of the Group. On the second day there will be discussions on papers which have been offered and accepted for printing in *Powder Metallurgy*.

The Committee of the Joint Group wish to emphasize that it is not their intention that Group meetings shall be restricted to the discussion of invited papers on particular themes; it is hoped that the meetings may, in fact, be devoted to the discussion of scientific and technological papers which have been submitted for publication without invitation. A leaflet detailing the preferred method of preparing mss. of papers for publication may be obtained from The Secretary, Powder Metallurgy Joint Group, 17 Belgrave Square, London SW1. Membership of the Group is international.

AFFILIATED LOCAL SOCIETIES

Staffordshire Iron and Steel Institute Annual Competition 1960

The Staffordshire Iron and Steel Institute has announced the rules for this year's annual competition:

(1) The competition is open to Associates and Members below the age of 28 years.
(2) The paper to be of a practical nature, related to the iron and steel trades and to be between 2500 and 3000 words in length, suitably illustrated and typewritten (double spacing).
(3) The paper must be an original contribution prepared specially for the Staffordshire Iron and Steel Institute.
(4) The paper shall be on one of the following subjects: (i) ironmaking, (ii) steel manufacture, (iii) foundry work, (iv) hot and cold working of steel, (v) fuels, (vi) refractories, (vii) engineering.
(5) Closing date for submission of papers shall be 31 December 1960.
(6) The announcement of the award will be made at the Annual General Meeting 1961.
(7) The award shall be to the value of ten guineas.
(8) The adjudicating panel shall consist of members of council who are specialized in the fields indicated under (4).
(9) The adjudicating panel shall have the power to co-opt appropriate authorities from within or without the Staffordshire Iron and Steel Institute.

Forms for application can be obtained from the secretary: G. Riley, Stewarts and Lloyds Ltd, Bilston Iron and Steel Works, Bilston, Staffs.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Annual Report 1959

The BISRA Annual Report for 1959, published last month, reviews the Association's many activities over the past 12 months. These include pilot-scale investigation of the processes taking place inside a blast-furnace in which a stationary charge is subjected to the conditions experienced by a normal charge during its passage down the stack; automatic control of arc furnaces, especially the linking of power input control with roof temperatures; and the use of oxygen, both in OH steelmaking and in controlled pre-refining of iron.

Considerable work has also been done on automatic forging and vacuum treatment of steel. The Plant Engineering and Energy Division has developed a system for the automatic processing of works data, and the use of computers as a management tool is one of the projects being investigated by the Operational Research Department. An automation section formed in the Physics Department is working on a scheme for the automatic inspection and deseaming of billets.

The Report clearly details the structure of the Association, and maintains a high standard of presentation and production.

SOCIETY OF CHEMICAL INDUSTRY

Corrosion Group

The next meeting of the Corrosion Group will be held at 14 Belgrave Square, London SW1 on Wednesday 15 June, from 10 am to 12.30 pm, and 2.15 pm to 5 pm, to discuss 'Oxidation of mild steel'.

The oxidation of mild steel by carbon dioxide has in recent reactor development been found to need special study, and the meeting has been arranged to provide an opportunity for discussion of this and analogous problems. A number of papers will be presented and, to encourage free expression of opinion, the discussion will not be recorded in detail.

The final titles of the papers are not yet known but the speakers and their subject matter are expected to be as follows:
The accelerating oxidation of mild steel in carbon dioxide by M. Davies and C. Moore; *Experimental investigation of oxidation by carbon dioxide* by C. S. Campbell and J. Boulton; *Effects of tramp elements in steel* by D. A. Melford; *The breakaway action in oxidation* by S. J. Gregg; *Electron microscope observations of oxidation* prepared by the Fulmer Research Institute; *Oxidation of steel in high-temperature alkaline waters* by G. M. W. Mann; *Oxidation of low-alloy steels in steam* by G. Wood.

The meeting is open to all and it is hoped that anyone interested in oxidation of steel will come and take part in the discussion.

INSTITUTION OF MINING AND METALLURGY

Recent Awards

The Council of the Institution of Mining and Metallurgy have announced the following awards:
Gold Medals of the Institution for 1959 have been awarded to Mr E. D. MCDERMOTT, A.R.S.M., and to Mr J. KRUTTSCHNITT, PH.B.
Honorary Membership of the Institution has been conferred on The Rt. Hon. Lord ROBINS, K.B.E., D.S.O., E.D., Sir REGINALD P. LINSTEAD, KT., C.B.E., D.SC., F.R.I.C., F.R.S., and on G. A. WHITWORTH, O.B.E., A.C.S.M., M.I.M.M.
'The Consolidated Gold Fields of South Africa Limited' Gold Medal for 1958–9 to S. C. NEWMAN, B.SC., B.A., A.M.I.M.M.
'The Consolidated Gold Fields of South Africa, Limited' Premium of Forty Guineas for 1958–9 to F. MENDELSOHN, PH.D., B.SC., A.M.I.M.M.
The 'Arthur Claudet' Student's Prize to H. N. RHODEN, PH.D., A.R.S.M., STUDENT I.M.M.
The 'William Frecheville' Student's Prize to M. J. WEST, A.R.S.M., B.SC., STUDENT I.M.M.

THE INSTITUTE OF METALS

Lecture by Professor Pauling

Professor Linus Pauling, of the California Institute of Technology, has accepted an invitation from the Metal Physics Committee of The Institute of Metals to lecture during his forthcoming visit to the UK. His subject will be 'The structure of metals and intermetallic compounds' and the lecture will be delivered at the Royal Institution, Albemarle Street, London, W1, at 6.30 pm on Monday 25 July 1960. Visitors will be welcome; tickets are not required.

FORTHCOMING CONFERENCES

Symposium on fatigue strength

A symposium on topical problems of fatigue strength, especially of large-size parts, will take place on 9–10 September 1960, in Prague, under the auspices of the Czechoslovak Scientific-Technical Association.

Papers on the following main topics will be discussed: (i) physical aspects of the origin and development of fatigue damage of metals; (ii) metallurgical and technological factors affecting fatigue strength; (iii) influence of size and shape of parts on fatigue strength and service life; (iv) influence of stress history on the fatigue strength of parts.

Further information is available from the Secretariat of the Symposium, c/o Československá vědecko-technická společnost, Široká 5, Praha 1—Staré Město, ČSR, Czechoslovakia.

EDUCATION

Current practice in fuel efficiency

The seventh annual residential refresher course of the National Industrial Fuel Efficiency Society will be held at the Clarendon Laboratory, Oxford, from 26 to 30 September 1960. This course covers a wide range of subjects and each of the lectures is presented by a speaker eminent in the special field to be covered and who will pay particular attention to practical application.

The subjects include coal and the industrial consumer, role of the central engineering workshop in the maintenance plan, oil burning efficiency, efficient use of gas in industry, recovery and use of waste heat in industry, improvement of electrical load factor, automation and its impact on the plant engineer, factors affecting the choice of industrial boiler plant, efficiency in drying processes, industrial application of low temperatures, value of instruments and automatic control, conservation of water, efficient use of compressed air, appraisal of atomic energy in relation to industry, incineration and utilization of waste materials, and 5 years' progress in fuel utilization.

Fee for the course, including accommodation, is £15 15*s*. and full details may be obtained from the course secretary, NIFES, Ailsa House, 181 King's Road, Reading Berks.

CJB scholarships

Constructors John Brown Ltd have entered into an agreement with The Institution of Chemical Engineers for the award of two scholarships. The purpose of these is to encourage research in chemical engineering and, in particular, in chemical plant design.

The scholarships are tenable at any educational institution in the United Kingdom in receipt of grants from the University Grants Committee, and having a department of chemical engineering under the direction of a professor of chemical engineering.

Further particulars may be obtained from Dr J. B. Brennan, General Secretary, The Institution of Chemical Engineers, 16 Belgrave Square, London SW1.

NEWS OF SCIENCE AND INDUSTRY

BNFMRA Annual General Meeting

The fortieth annual general meeting of the British Non-Ferrous Metals Research Association held at the Savoy Hotel on 11 May was the first to be presided over by Mr F. C. Braby, M.C., D.L., who took over chairmanship of council from Dr Maurice Cook, C.B.E. in January. The continued interest and help of Dr Cook in the work of the Association is assured by his co-option to council.

Elections to the council of the Association at the annual general meeting included:

L. Robert Carr, M.P., L. Rotherham, R. D. Burn, S. E. Clotworthy, C.B.E., A. H. Carmichael, G. Hunt, and Dr N. P. Inglis.

During 1959, further contributions towards the new laboratory block opened a year ago brought the total from members plus DSIR grant earned to £107 500, a substantial proportion of the £130 000 which the expansion has cost.

The expanded research programme, which the extra laboratory space and increased industrial support allows, necessitates an increase in staff. Seven additional qualified scientists were engaged in 1959, bringing the total staff to just over 170, and recruitment of more staff is proceeding.

Among the new researches listed in the Association's annual report are investigations into the prevention of air pollution; effluent treatment; nickel additions to gunmetal; preheating atmospheres for copper cakes and wire bars; springiness in copper wire; hard spots in cast and extruded brasses; butt welding of high-conductivity copper; and corrosion cracking of copper alloys. In the light-alloy field new researches include directional properties of medium-strength alloys and tests for serviceability of bright anodized aluminium. In the nuclear energy field there are new researches on the protection of niobium by plating, absorption of hydrogen by metals, and intercrystalline fissuring and cavitation. A fundamental study of the oxidation of zinc has also been started, and a new study of cobalt additions to nickel plating solutions.

Inco board changes

The International Nickel Company of Canada Ltd announce that Mr Henry S. Wingate, president of the company since 1957, has been elected chairman of the board. He succeeds Dr John F. Thompson, who joined the company in 1906 and has been chairman since 1951. Dr Thompson remains chairman of the executive committee and honorary chairman.

Mr J. Roy Gordon has been elected president, and Mr Ralph D. Parker senior vice-president.

Developments at ESC

English Steel Corporation Ltd announce that the Iron and Steel Board has agreed to further developments at Tinsley Park, Sheffield. The scheme has the support of the British Iron and Steel Federation.

It is proposed to replace billet mills installed at River Don and Stevenson Road works more than 40 years ago with a modern installation comprising one 42-in. blooming mill and two 32-in. billet mills which will permit more economical production of a larger volume of alloy and special carbon steel billets. The capacity for billet production will be increased by 250 000 tons per annum, some of which will be processed in other plants of the group. In addition, the bar rolling mills at River Don works are being replaced by new mills which will give an anticipated additional yearly output of 60 000 tons.

To provide the additional steel required, three 100-ton electric melting furnaces are being installed and with this addition the total melting capacity of the ESC group for the production of alloy and special carbon steels will be approaching 1 m. tons per year. The estimated cost of the project is £26 m. and it is planned to be in full operation in 1963. The plant will be operated by English Steel Rolling Mills Corporation Ltd, a wholly owned subsidiary company.

Rolling starts at Durgapur

The first ingot was successfully rolled and sheared early last month in the new Durgapur steelworks which the British consortium, ISCON, is building in West Bengal. During the first day's operation, 250 tons of ingots were rolled on the primary rolling unit of the works, a Davy–United 42-in. blooming mill.

The 32-in. intermediate blooming mill has also come into service.

New heavy oxygen cutting rig

A new heavy oxygen cutting rig for mild steel and steel castings up to 5 ft thick has been developed by British Oxygen Gases Ltd. It incorporates the company's latest nozzle mixing blowpipe using propane as the fuel gas.

Apart from providing industry with a means of cutting greater thicknesses, the new equipment also improves the ease of cutting, safety, and quality of finish. The cutter is particularly suitable for removing risers from castings, as well as for breaking up large forge hammers, ladle bottoms, and other scrap material for re-melting or disposal.

Reavell-Fahie expand

Reavell and Co. Ltd and Reavell-Fahie Ltd, who played a large part in the instrumentation and control in the recently completed 'M' scheme of the Steel Company of Wales Ltd, have completed an extensive programme of reorganization and re-equipping. The new facilities at Ipswich will enable the companies to participate in future measurement and control schemes in the industry.

New industrial films

Three new industrial films were given press previews in London last month.

The first, *Pipeline construction*, made for William Press and Son Ltd in co-operation with the Southern and South Eastern Gas Boards, opens with some interesting 'stills' of the earliest known examples of piping (Chinese bamboo pipes dating from about 5000 B.C.). It then goes on to show the 'spread method technique' which in open country allows considerable lengths of welded pipeline to be laid with minimum disturbance to farmland. Shots of the final preparation of the pipe and its inspection by ultrasonic and radiographic methods indicate the complexity of present-day pipelaying.

Two films made for The United Steel Companies achieve the high standards of their previous films. *Out of the forest* deals with the work of the United Coke and Chemicals Company in carbonizing coal to obtain the metallurgical coke used in the blast-furnaces at Appleby-Frodingham. It shows how carbonization produces many chemical derivatives from which are produced saccharine, nylon, road tar, dyes, paints, floor tiles, fertilizers, and plastics including synthetic resins.

Stone into steel uses less conventional film techniques to show how 11 000 people at Appleby-Frodingham produce nearly 1½ m. tons of steel each year. There is no spoken commentary to the film, but music specially composed for it heightens the effect of contrasting sequences.

All three films are in colour and are available on loan from the companies concerned.

Blast-furnace linings flown to South Africa

Blast-furnace linings manufactured by Carblox Ltd of Loxley, near Sheffield, and weighing nearly 10 tons were flown from Manchester to an ironworks in South Africa in 24 h last month.

The consignment was required for forming the carbon lining around the tuyeres and slag notches of a blast-furnace which has been operating for some years and which may fail at any time. Rather than risk a delay in transportation by sea, and a possible loss of output

of up to £20000 per day, the linings were flown out by chartered aircraft.

Contract news

The *Richardsons Westgarth Group* have recently received an order from one of the major oil companies for eight combustion gas turbo-compressors, for installation overseas.

The *Wellman Smith Owen Engineering Corporation Ltd* has been awarded substantial contracts for steelworks plant and equipment for Richard Thomas and Baldwins' Spencer works near Newport. Included in these contracts are the 62-in. continuous pickle line for steel sheets, ingot stripping machines, and a number of heavy-duty cranes for the slabbing mill and hot-sheet finishing bay. Deliveries of the first units of this equipment are scheduled for December 1960. In addition, the Wellman Corporation are collaborating with VOEST of Linz, Austria, for the joint supply and erection at the Spencer works of L–D steelmaking plant, the main items comprising three 100-ton L–D vessels with oxygen lances and auxiliary equipment and two 1200-ton hot-metal mixers. The L–D plant will be delivered and erected ready for operation in September 1961.

Changes of Address

Thos. W. Ward Ltd have opened a new branch office at Duchy Road, Salford, Lancs. The company's office at Corporation Street, Manchester has been closed and all business transferred to the Salford office.

The Alloys Division of Union Carbide Ltd announce that their Glasgow office is now operating from Cornhill House, 144 West George Street, Glasgow C2 (Douglas 7753).

CORRIGENDA

In the paper *Diffusion and solubility of sulphur in iron and silicon–iron alloys* by N. G. Ainslie and A. U. Seybolt (*JISI*, 1960, **194**, March, 341–350) the caption to Fig.5 (p.344) should read 'Autoradiographs of specimens given diffusion anneals at the following temperatures (*top*) 950°C (*centre*) 1000°C (*bottom*) 1100°C. Note that fast grain-boundary diffusion is evident still at 1000°C".

In the paper *The location of Byrkeknott, a 15th century smelting site* by R. F. Tylecote (*JISI*, 1960, **194**, April, 451–458) Fig.1 on p.452 should have been credited 'Crown copyright reserved'.

INDUSTRIAL PUBLICATIONS RECEIVED

Davy and United have issued a broadsheet intended to provide an all-round view of the group's activities.

Simon-Carves Ltd detail some of their plant in a booklet *Steelmaking and electro-precipitation*.

'Ribback' hammer forging machines are described in a leaflet from Usine de Wecker, S.A.R.L. Wecker, Luxembourg.

Head Wrightson and Co. Ltd describe hot-metal mixer cars made by them under licence from the Treadwell Company of America, in a recent leaflet.

Air Power News is a new broadsheet dealing with the products and activities of the air power division of Joy–Sullivan Ltd.

The golden jubilee of APV Ltd is marked by a special brochure.

Publication No.83 from W. C. Holmes Ltd describes the range of Holmes–Standard bag filters.

DIARY

29 May–11 June THE IRON AND STEEL INSTITUTE—Special meeting in Italy.

30 May–2 June FIRST INTERNATIONAL PIPES AND PIPELINES EXHIBITION—Earl's Court, London.

8–10 June SOCIETY FOR ANALYTICAL CHEMISTRY and GAS CHROMATOGRAPHY DISCUSSION GROUP—3rd symposium on gas chromatography—Assembly Rooms, Edinburgh.

9–13 June TUBE STEEL ASSOCIATION—Conference—North Berwick.

12–18 June INTERNATIONAL INSTITUTE OF WELDING—Annual Assembly—Liège, Belgium.

14–18 June ASSOCIATION OF MINING, ELECTRICAL AND MECHANICAL ENGINEERS—Conference—Blackpool.

15 June SOCIETY OF CHEMICAL INDUSTRY—Corrosion Group—Meeting on oxidation of mild steel—14 Belgrave Square, London SW1, 10 am.

20–23 June INSTITUTE OF MECHANICAL ENGINEERS—Conference—Belfast.

21–25 June INSTITUTE OF BRITISH FOUNDRYMEN—Annual Conference—Malvern.

22–24 June BRITISH IRON AND STEEL RESEARCH ASSOCIATION—14th Junior Steelmaking Conference—Scarborough.

25 June–8 July INTERNATIONAL MACHINE TOOL EXHIBITION—Olympia, London.

28–30 June INSTITUTE OF MINING ENGINEERS—Conference—Cardiff.

4–7 July ELECTRONIC COMPUTING CONFERENCE—Harrogate.

5–6 July BRITISH IRON AND STEEL RESEARCH ASSOCIATION—Conference on heat-treatment practice—Harrogate.

BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on p.102 of the May 1960 issue of the *Journal*:

Processes of forming metal under pressure in the liquid and plastic state and their development.
PLYATSKII, V. M., *Lit. Proizv.*, 1956, (6), pp.7–11. (£5 15*s*. 0*d*.) [**1384**

Contributions to steelworks chemistry sampling and determination of hydrogen in steel.
STETTER, A., *Stahl u. Eisen*, 1959, July 23, pp.1087–1090. (£2 10*s*. 0*d*.) [**1458**

The production of power and blast in the top gas power plant of an iron and steelworks by means of a 14 mW gas turbine.
WEYEL, A. *et al.*, *Stahl u. Eisen*, 1959, Oct. 15, pp.1471–1478. (£6 5*s*. 0*d*.) [**1493**

Pressure welded austenitic–ferritic composite junction pieces (Mannesmann-type joints).
LINDEN, H., and HENNECKE, H., *VGB Mitt.*, 1958, June, pp.165–175. (£5 15*s*. 0*d*.) [**1512**

Non-oxidizing heating of steel in open-flame furnaces.
KUROEDOV, V. A., *Kuznechno-shtamporochnoe Proizv.*, 1959, Jan., pp.25–31. (£6 10*s*. 0*d*.) [**1541**

Development of drives and electrical machines in rolling mills.
NÜRNBERG, W., *Stahl u. Eisen*, 1959, May 14, pp.694–703. (£7 10*s*. 0*d*.) [**1550**

Conchoidal fractures in nickel–vanadium steel.
EMINGER, Z. D., *Neue Hutte*, 1959, Oct., pp.596–608. (£5 15*s*. 0*d*.) [**1553**

Critical study of the determination of hydrogen in steel.
CALMETTES, J. *et al.*, *Mem. Sci. Rev. Mét.*, 1959, Dec., pp.641–655. (£7 10*s*. 0*d*.) [**1563**

The effect of niobium on the high temperature properties of austenitic stainless steel.
INOUE, S. *et al.*, *Tetsu to Hagane*, 1958, Sept., pp.1132–1134. (£4 5*s*. 0*d*.) [**1568**

The employment of an electric integrator for the study of the temperature distribution of the hearth and foundation of a blast-furnace.
YUSHKIN, V. V., *Stal'*, 1957, Sept., pp.779–787. (£5 10*s*. 0*d*.) [**1578**

The problem of pinhole porosity in steel castings.
WLODAWER, R., *Giesserei*, 1960, Jan. 14, pp.1–7. (£5 5*s*. 0*d*.) [**1608**

Papers from 'Continuous Casting of Steel. Proc. 1st All-Union Conference, 17–19 October, 1955'. *Moscow, Akad. Nauk*, 1956. [**1614, 1616, 1618**

Peculiarities [and defects] of the formation of billets produced by continuous casting.
ZIGEL', O. D., pp.164–177. (£5 15*s*. 0*d*.) [**1614**

An investigation of the mechanical properties of steel during solidification and an analysis of the process of the formation of hot cracks during continuous casting.
POSTNOV, L. M., and GULYAEV, B. B., pp.212–222. (£6) [**1616**

On planning scientific investigations on the continuous casting process.
SAMARIN, A. M., pp.267–270. (£2 15*s*. 0*d*.) [**1618**

Welded and expanded joints for high pressure pre-heaters.
HAFERKAMP, H., *VGB Mitt.*, 1959, Oct., pp.365–367. (£2 15*s*. 0*d*.) [**1622**

The effect of an increased iron sulphate content in sulphuric acid pickling solutions on the technological properties of pickled wires.
EISENHUTH, C., and MARTIN, M., *Stahl Eisen*, 1959, Dec. 10, pp.1862–1867. (£4 5*s*. 0*d*.) [**1634**

Contribution to the complete determination of the state of residual stresses in hollow cylinders.
LAURENT, P. *et al.*, *Forsch. Ing.*, 1959, vol.25 (2), pp.44–54. (£5 15*s*. 0*d*.) [**1639**

Research into the flow pattern of combustion gases in, and the heating of, soaking pits by means of models.
ČERNOCH, S. *et al.*, *Hutnik* (Prague), 1960, vol.10, (1), pp.21–24. (£5 10*s*. 0*d*.) [**1640**

Bonding of steel with plastic adhesives.
MÖHLER, K., *VDIZ*, 1959, Jan., pp.1–8. (£6) [**1648**

Reducing segregation in rimming steel. I. Blowing oxygen into ingots.
SHAO, Hsiang-hua and PANG, Yueh-chu, *Acta Met. Sinica*, 1958, (2), pp.98–109. (£9) [**1657**

Effect of low temperatures on the strength of eleven plain carbon steels (up to 0·12%C) under bi-axial stressing.
KRISCH, A., *Arch. Eisenhüt.*, 1960, Jan., pp.19–24. (£3 15*s*. 0*d*.) [**1658**

The most common types of corrosion in stainless steels.
BERG, S., *Chemische Rundschau*, 1959, April 1, Beilage 2, pp.185–189. (£4 10*s*. 0*d*.) [**1662**

Forces operating in cold roll forming.
DAVYDOV, V. I., and PCZYREVSKII, Yu. K., *Stal' Rolling and Tube Prod. Supp.*, 1959, pp.95–103. (£4) [**1680**

Investigations on the effect of the rolling conditions on the properties of hot-rolled low carbon steel strip. I. Structure of the scale and behaviour in pickling.
DAHL, W., and LUEG, W., *Stahl Eisen*, 1958, March 20, pp.368–377. (£6 10*s*. 0*d*.), and *CDS Circ. d'Inform. Tech.*, 1958, (8), pp.1601–1622. [**1681**

Heat migration through the outer metal oxide layer during the dissociation of lumpy carbonates.
BALAZSOVICS, G., *Radex Rund.*, 1959, Dec., pp.714–721. (£3 15*s*. 0*d*.) [**1682**

The rotor steel works of Ilseder Hütte.
KÖHLER, W., *Klepzig Fachberichte*, 1959?, pp.341–343. (£2 15*s*. 0*d*.) [**1688**

Graphical method for determining forces and power requirements in drawing bars and tubes.
MÄKELT, H., *Industrie-Anzeiger*, 1959, May 19, pp.28–31. (£3) [**1689**

Contribution towards the knowledge of the behaviour of hydrogen in steel.
HOFMANN, W., and VIBRANS, G., *Mem. Sci. Rev. Mét.*, 1960, Feb., pp.88–90. (£2) [**1719**

Determination of cubic chromium carbide $Cr_{23}C6$ in steel.
POPOVA, N. M., and SOROKINA, K. P., *Zavods. Lab.*, 1953, (9), pp.1033–1034. (£1 10*s*. 0*d*.) [**1721**

The Rilem-Cemburean method for testing the strength of cement.
DUTRON, R., *Zement-Kalk-Gips*, 1960, Feb., pp.64–70. (£3 10*s*. 0*d*.) [**1722**

The testing of cement by the Rilem-Cemburean method.
KEIL, F., and MATHIEU, H., *Zement-Kalk-Gips.*, 1960, Feb., pp.70–78. (£4 10*s*. 0*d*.) [**1723**

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

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ABSTRACTS

These abstracts are also available on index cards in advance of publication in the *Journal*, each abstract being classified under the Universal Decimal system (UDC). Details and subscription notes can be obtained from the Secretary, The Iron and Steel Institute.

MINERAL RESOURCES

Estimating ore reserves follows logical steps J. A. Patterson (*Eng. Min. J.*, 1959, **160,** Sept., 111–115) Collecting and assessing data, and systems of calculation are reviewed.

The Frodingham ironstone bed, II (*Appleby Frodingham News*, 1959, **12,** (2), 4–11) Open-cast working and methods at the Santon and Dragonby underground mines are briefly surveyed.

The iron ore deposit at Tindouf (Sahara) R. Michel and L. Clariond (*Ann. Mines*, 1960, Jan., 1–17) With maps, plans, and illustrations and estimates of reserves.

Unfavourable prospects for Mindale Hill (*Min. J.*, 1959, **253,** Oct. 30, 414) A note from the *Geological Survey of Nyasaland, Report* FH/33, that quality of the deposit may not be high enough to justify export, and may be too small for commercial working.

Iron King magnetite deposit A. R. Crawford (*Min. Rev. South Australia*, 1957, (106), 63–69) An account of a small deposit with sketch map and assay.

The iron ore industry of Minnesota and the problem of depleted reserves C. L. Horn, jun. (*Degree Thesis, Princeton University*, 1950, April 24, pp.195) The geology and history of the development of the Minnesota iron deposits are described, and the production, reserves of ore in relation to estimated future requirements, and economic aspects are discussed. As it has been shown that the high-grade deposits are becoming depleted, the prospects of developing new sources are considered (116 refs).

Metamorphosed iron formation in Southwestern Labrador D. M. Knowles and R. G. Gastil (*Can. Min. Met. Bull.*, 1959, **52,** Aug., 503–510) The geology of the deposit is described.

ORES—MINING AND TREATMENT

A half century of progress in metal mining—I G. K. Allen (*Min. Mag.*, 1959, **101,** Oct., 153–169) Brief sections on explosives, surface mining, opencast methods and underground mining are included, and equipment is reviewed.

Marquesado—Spain's largest iron mine J. B. Huttl (*Eng. Min. J.*, 1959, **160,** Dec., 96–99) The development, layout, capacity, and operation are described of the Minas del Marquesado, mined by Compania Andaluza de Minas S.A. in Granada Province.

An electro-pneumatic constant-weight feeder for ore-blending E. I. Lowe and M. J. Harris (*Trans. Soc. Instr. Techn.*, 1959, **11,** Sept., 159–162) The weight on a 4 ft length of conveyor is measured and the rate of feed is regulated accordingly.

Organic carbon and sulphur in the Kerch iron ores V. F. Malakhovskii (*Doklady A.N.* 1959, **128,** (6), 1262–1265) A study of the distribution of organic carbon and sulphur in the Kerch ore related to the depth of the sediments is reported.

Effects of structure and unsaturation of collector on soap flotation of iron ores S. R. B. Cooke, I. Iwasaki, and H. S. Choi (*Min. Eng.*, 1959, **11,** Sept., 920–927) All soaps used had a sharply defined correlation between pH and selectivity index. In general the more highly unsaturated soaps (from fish oils) were unsuitable for floating iron oxides but were powerful and selective collectors for chert and Ca-activated quartz at pH > 11.

Industrial metal detectors with special reference to the sorting of ores and coal G. Charles (*ASEA Research*, 1958, (1), 131–146) A review of the available equipment is followed by a description of the ASDET, an instrument developed by the ASEA research laboratories. The ASDET is simple and rugged in construction, uses only four long-life valves, and requires no adjustment or balancing. It is suitable for detecting 'tramp' metals in iron ores, and, among other applications, for the grading of ore and recovery of metals from slag.

Stockpiling taconite in the U.S.: Pellet handling by belt conveyor stacker (*Iron Coal Trades Rev.*, 1960, **180,** Jan. 1, 31–33) The largest belt conveyor stacker in the United States, designed and erected by the Link-Belt Company, has recently been installed for stockpiling taconite pellets at the world's largest taconite pelletizing plant on the Mesabi Range. It stockpiles up to 5×10^6 t of pellets each winter when the Great Lakes are closed to navigation.

Dryer for iron ore Buell Ltd (*Edgar Allen News*, 1959, **38,** Dec., 275) A 50-t/h drum is shown.

New technique in bulk carrying Hall, Russell & Co. Ltd (*Brit. Eng. Transport*, 1959, **42,** Nov., 125) An account of the M.V. *Holmside*, 6 500 t for carrying ore or sugar in bulk.

Iron ore at Hartlepool J. Grindrod (*Min. Mag.*, 1959, **101,** Oct., 183–184) Unloading facilities at the docks are briefly described. The use of the skid shovel is particularly mentioned.

Regarding the sulphidization of magnetite N. G. Moleva and P. S. Kusakin (*AN SSSR Ural. Inst. Met.*, 1959, (3), 15–19) The magnetite of oxidized nickel ore and agglomerates contains appreciable amounts of nickel. To facilitate the extraction in the matte and reduce its percentage in slags, magnetite should be broken down. With the theoretical amount of sulphur in the gaseous phase the original magnetite is practically totally sulphided between 1 150–1 200° after 30–45 min. Under conditions of actual charging of oxidizing ores the primary magnetite is sulphided to an appreciable extent only in the tuyere zone and the secondary magnetite at a distance of 500–600 mm from the tuyere level.

Operational results obtained over long periods at the Louvroil works with graded crushed ore J. Guerbois and J. Daville (*Centre Doc. Sidér. Circ.*, 1959, **16,** (3), 605–637) Long-term trials on graded ore, in which fines and pieces over 70 mm were eliminated from the burden, gave a greatly improved blast furnace performance; coke consumption was comparable with that obtained with mixtures of crushed ore and sinter.

Redistribution of moisture during the sintering of iron ore A. A. Sigov (*Izvest. VUZ. Chern. Met.*, 1958, Aug., 7–12) Experiments were made in which the sintering process was interrupted and the charge structure and zone distribution were examined. After 1½–2½ min. the bottom layer contained up to 9% condensed water but this did not increase further and indeed tended to fall. Temperatures were measured at various levels and heat evolution from condensation was detected and when this rises to the dew-point no further condensation occurs. This is generally progressive through the bed, but the zone contracts and finally disappears as the high temperature zone passes downwards.

Research in the company organization H. K. Worner (*BHP Rev.*, 1959, **36,** Oct., 10–13) A review of the fields in which work is proceeding: ore dressing, coal and coke, sinter and, very briefly, other topics.

Will it be sinter or pellets? Pellets may revolutionize blast furnace charging G. J. McManus (*Iron Age*, 1959, **184,** Dec. 24, 21) Conjecture is made as to the relative merits of sinter and pellets for blast-furnace charging, and which product will find favour with ironmakers. A remarkable output is reported from an Armco Steel Co. blast-furnace charged with high-grade taconite pellets. Rival merits of the two agglomerates are still being evaluated.

Kinetic phenomena in roasting and reduction T. Rosenkvist (*Tidsskr. Kjemi. Berge. Met.*, 1959, **19,** Oct. 15, 126–130) The mechanism of the reduction of hematite with CO, and the influence of various factors on the reduction rates of iron ores are discussed, with reference to the literature and to work by the author (22 refs).

The reducibility of iron ores H. Schenck, N. G. Schmahl, and G. Funke (*Forsch. Wirts. Nordrhein-Westfalen, No.562*, 1958, pp.101) Tests on the 'indirect reduction' of iron ores with CO are reported. The ores are classified according to their reducibility, the results are presented in a table. Not only origin but also surface properties which can be varied at will by ore preparation have a great effect. The

reduction rate was highest between 900 and 1000°C according to the ore. Pressure, e.g. 2 kg/cm², had a detrimental effect, the CO consumption increased many times. Some model tests as an analogy to the processes taking place in the blast-furnace were also carried out (36 refs).—T.G.

Fundamental researches of making self-fluxing sinter and the practice with its 100% sinter burden K. Kasai, T. Sanematsu, and S. Watanabe (*Sumi. Met.*, 1959, **11,** July, 170–180) The mineralogical constitution of self-fluxing sinter includes CaO, Fe_2O_3, 2 CaO, Fe_2O_3, tridymite, melilite, etc. Its reducibility depends on the great proportion of calcium ferrite instead of fayalite. The addition of limestone to the raw material slightly decreases the strength of sinter and desulphurization rate in sintering, but not the yield. Coke rates should be reduced below 550 kg per tonne of iron and furnace productivity increased beyond 1·3 tonnes/day per m³ of furnace vol.—K.E.J.

Waste products from zinc manufacture used to increase the basicity of iron ore sinter A. Maslanka and M. Kowalewski (*Prace Inst. Hutn.*, 1959, **11,** (5), 251–260) The use of these waste products as an addition to the sinter was found unsatisfactory for the following reasons: (1) The chemical composition of the waste is not uniform preventing the formation of sinter with constant basicity; (2) The addition of this waste causes a rapid rise of zinc content in the sinter. This in its turn produces lower output and higher coke consumption. In addition the high zinc content in the burden causes scaffolding in the blast furnace and gas cleaning plant and cracking of the furnace shell. The process could possibly be employed if the zinc could be removed effectively from the waste or if the waste product were bedded before sintering.

Sintering investigations with pre-agglomerated burdens F. W. Kinsey and C. A. O'Malley (*Trans. Met. Soc. AIME*, 1959, **215,** Dec., 1008–1014) The authors report on a study of experiments in the use of a pre-agglomerated burden as a means of increasing the production of sinter. They found that in a pre-agglomerated sinter burden the total moisture is the main factor controlling sintering rate. Sinter strength is a direct function of the carbon content of the original burden. Sinter production rate is an inverse function of the % concentrates in the burden. Production rate was strongly affected by bentonite additions of up to 1%, it also depends on pellet size (19 refs).

The problem of dust removal in sinter plant projects J. Aniola (*Hutnik*, 1960, **27,** (1), 15–22) The author considers the problem in relation to various types of plant in operation and the attempts made to overcome it. He arrives at the following conclusions: (1) The materials to be processes should be of suitable grain size and contain the maximum permissible quality of moisture; (2) The plant should be hermetically sealed; (3) Polluted air should be reintroduced into the process and not released to the atmosphere; (4) Powdery and hot materials should be transported pneumatically or with vibrating conveyors.

Kinetics of iron oxide reduction W. M. McKewan (*Trans. Met. Soc. AIME*, 1960, **218,** Feb., 2–6) Pellets were reduced in H_2 at 0·07–0·97 atm. at 400–1050°C. The rate of reduction per unit area is const. with time and proportional to partial pressure of H_2. Enthalpy of activation of 400–550°C is 14900 cal per mol and at 600–1050°C is 15300 cal/mol.

Graphical technique for multistaged fluidized bed operations as applied to iron-ore reduction H. P. Meissner and F. C. Schora (*Trans. Met. Soc. AIME*, 1960, **218,** Feb., 12–21) A modification of the McCabe–Thiele method for distillation calculations is used.

FUEL—PREPARATION, PROPERTIES AND USES

Electrical equipment for coal preparation plants W. H. Foster and F. Egerton (*Min. Elect. Mech. Eng.*, 1959, **40,** Oct., 84–94, discussion 94–95) The Westoe and Easington plants are described with special reference to the electrical equipment.

The cleaning of fine coal by dense-medium cyclone T. Imaizumi, T. Nomizu, and Y. Yamabe (*Ann. Rep. Eng. Res. Inst. Tokyo*, 1959, **18,** Sept., 43–48) A report on the work of the test-plant at Toyosato colliery, Japan.

Chemical structure and properties of coal. XXV. The carbonization of coal models P. M. J. Wolfs, D. W. van Krevelen, and H. I. Waterman (*Fuel*, 1960, **39,** Jan., 25–38) Model substances, prepared to imitate the structure of coal, were synthesized by condensation of formaldehyde with substituted and unsubstituted hydrocarbons. The progress of carbonization was followed by radiochemical and thermogravimetric methods. The mechanisms of primary and secondary carbonization are discussed and explained.—T.G.

Mechanisms of coal pyrolysis. I. On the nature and kinetics of devolatilization N. Berkowitz (*Fuel*, 1960, **39,** Jan., 47–58) Analysis of the kinetics of weight-loss curves measured at a series of constant temp. leads to the suggestion that they are governed by a diffusion process and that the decomposition reactions at any one temp. must be relatively fast.—T.G.

New coal and coke loading installation for Emden J. Grindrod (*Min. Mag.*, 1959, **101,** Sept., 101–104).

A note on Polish carbonization practice: the importance of coal stamping A. Szpilewicz (*J. Inst. Fuel*, 1959, **32,** Dec., 568–570).

New coking plant uses centralized control systems (*Process Control Autom.*, 1959, **6,** Sept., 376–382) A description of the Murton plant.

Simulated coke oven operations in new research laboratory aid industrial coal quality control (*Ind. Heat*, 1960, **27,** Jan., 106–108) At Consolidated Coal Co., research equipment includes a 30-lb movable-wall coke oven to determine coking pressures; and a spec al oven to measure expansion and contraction of the charge.—K.E.J.

The swelling and contraction of briquettes during carbonization A. D. Dainton and W. G. Kaye (*J. Inst. Fuel*, 1959, **32,** Dec., 571–578).

Twenty-sixth blast furnace conference T. P. Colclough, J. P. Graham, and S. D. Carson (*BISRA publication*, 1958, pp.72). **A general review of the influence of input on blast furnace performance** T. P. Colclough (3–7). Thermal data are given. **Recent research in coking technology** J. P. Graham (7–11). **Full scale experiments in the production of better coke** S. D. Carson (11–14).

The quality of metallurgical coke in the United States (1958) D. Sanna (*Centre Doc. Sidér. Circ.*, 1959, **16,** (9), 1967–1975) The distribution, composition, and mechanical properties of USA coke are reviewed.

Desirable properties of cupola coke L. W. Bolton (*Found. Trade J.*, 1959, **107,** Sept. 24, 211–213) Summary of an IBF sub-committee report.

Automatic apparatus for the detection and recording of oxides of nitrogen in coke oven gas J. Pierrain (*Chim. Anal.*, 1959, **41,** Dec., 477–485).

Sub-committee for furnace firing by coke oven gas. Meeting held 15 Oct., 1957 G. Decamps (*Centre Doc. Sidér. Circ.*, 1959, **16,** (3), 685–689) Problems connected with the need to make use of increasing amounts of coke oven gas in France for furnace firing are discussed.

The story of operation flox L. Reeve (*Appleby Frodingham News*, 1959, **12,** (3), 4–15) An account of the fluidized oxide process for coke oven gas desulphurization and its development.

AIR POLLUTION AND SMOKE

Reducing atmospheric pollution J. F. Pottinger (*Austral. Eng.*, 1959, **52,** Oct., 71–77) The usual varieties of plant for all sorts of dust and smoke are reviewed.

New detectors gang up on air pollution C. C. Van Soye (*Chem. Eng.*, 1959, **66,** Nov. 30, 48) A new dust sampler and a hydrocarbon monitor are announced.

Methods of dust and fume disposal W. A. Darrah (*Ind. Heat.*, 1960, **27,** Jan., 70–82) A review, dealing with spray, absorption, electrical checker, catalytic and electrostatic precipitation methods, with some comparisons for various applications.—K.E.J.

Purification of steelworks fumes: basic Bessemer plant and procedures for the refining or pre-refining of pig iron by means of pure oxygen L. Septier and P. Leroy (*Centre Doc. Sidér. Circ.*, 1959, **16,** (3), 651–678) The characteristics of the brown fumes evolved, in particular with the use of pure O_2, are described, and a critical review is given of cleaning methods; cyclones, single and multistage, and electrostatic filters, and bag filters (22 refs).

The fight against dust and silicosis in mines and smelting works of the German Democratic Republic: organization H. Jung (*Technik*, 1960, **15,** Feb., 83–87) The bye-laws for the prevention of silicosis, the organization of the research stations and their tasks and care of patients suffering from silicosis are described. There were a total of about 11800 silicosis cases in the German Democratic Republic, the highest number was in coal mining followed by the porcelain industry.—T.G.

Blast-furnace-gas cleaning for iron and ferro-manganese production J. S. Mackay and J. F. Kearns (*Trans. ASME J. Eng. Power*, 1960, **82,** Jan., 68–72) A process for removing the superfine smoke from Fe–Mn blast-furnace gases is described. The method does not require a great capital outlay and its operating costs are low. The method, its chemistry and physical equipment is detailed and illustrated.—T.G.

An automatic dust sampler E. R. Groutsch (*Austral. Inst. Min. Met.*, 1959, Sept., 165–189) A venturi for use in a flue is described and the theory indicated.

A routine sampler for detecting variations in the emission of dust and grit B. Lees and M. C. Morley (*J. Inst. Fuel*, 1960, **33,** Feb., 90–95) The device was developed primarily for boiler plant.

TEMPERATURE MEASUREMENT AND CONTROL

Pyrometry: science of high temperature measurement F. P. A. Robinson (*Eng. Found.*, 1959, **25,** Oct., 39–41) A general review of all types.

Care and maintenance of pyrometric equipment E. Beaver (*Eng. Found.*, 1959, **25,** Oct., 41–43, discussion 43–44) Notes on common faults.

The measurement of flame temperatures F. Rössler (*Z. Erzberg. Metallhüt.*, 1960, **13,** Feb., 74–78) Theoretical. The author discusses the principles of optical temperature measurement, the radiation laws, the emission of non-black bodies, thermal radiation, and the radiation of metals (17 refs).—T.G.

A simple, optical pyrometric method for the direct measurement of the true temperature of glowing metals C. Tingwaldt (*Z. Metallk.*, 1960, **51,** Feb., 116–119) The light emitted from glowing solids is polarized to a certain extent varying with the direction of emission. By superimposition, by reflection, of non-polarized light of the same colour a light beam from the glowing body can be obtained that is no longer polarized and therefore—according to Kirchoff's law—corresponds to the light emitted from a black body. An apparatus using this effect is described.—T.G.

Platinum/platinum–rhodium thermocouples for temperature measurements in the foundry E. R. Perry (*Fond. Belge*, 1959, **29,** Sept., 201–205) The principle of the thermocouple is described, and its construction, range, and precautions to be observed in its use reviewed.

Two thermocouples suitable for measurement of temperatures up to 2800 C D. A. Davies (*J. Sci. Instr.*, 1960, **38,** Jan., 15–17) W/26%Re–W and Ta/26%Re–W are used.

Zirconia-tipped thermocouple for measuring the temperature of liquid steel P. A. Sorokin (*Ogneupory*, 1959, (11), 517–522) The first results of testing the thermocouple tips of ZrO_2 under laboratory conditions have shown that they can be used for long duration continuous temp. measurements of liquid steel both in the furnace and in the ladle. More experiments are necessary, before a final conclusion can be reached.

REFRACTORY MATERIALS

Refractories and minerals J. F. Hyslop (*J. Metallurg. Club*, 1958–59, (11), 36–38) The expansion of chrome–magnesite bricks and the analysis of their hot face, centre, and cold end are examined. The ionic potential of cations and four types of reaction of refractory-slag mixtures are discussed.—S.H.–S.

Refractories keep pace with metals. I L. L. Gill (*Canad. Metalw.*, 1959, **22,** Nov., 42–43, 69) A review.

Preparation of pure oxide refractories by slip casting G. H. Chalder (*RDB(S)/TN*–2021, 1952, Feb., pp.10; from *Nucl. Sci. Abs.*, 1959, **13,** Sept. 30, 2179) Techniques of production of alumina ware are reviewed and a new method is evolved.

Manufacture of forsterite bricks from asbestos waste P. S. Mamykin and Yu. V. Syreishchikov (*Ogneupory*, 1959, (12), 529–538) Asbestos waste may form the main ingredient in the manufacture of high-grade forsterite bricks with a porosity below 20%, when used with 30% magnesite. The charge can be finely ground in the process of the preparation of the forsterite sinter. This makes it possible to use serpentinites, talc, talc-carbonates, and other materials. Iron oxides must also be included so as to raise resistance to wear in the regenerator checkers of OH furnaces.

Metallurgical magnesite powder with increased calcium oxide content used in O.H. furnaces V. A. Bron, L. B. Khoroshavich, G. A. Petrov, Zh. A. Vydrina, and A. I. Uzberg (*Ogneupory*, 1959, (12), 553–560) Investigations have shown that metallurgical magnesite powder with 9–14%CaO may be used in fettling the hearths of OH furnaces. The physical and chemical properties are not affected by large variations in the CaO content, say from 4–5 to 12–14%.

Fused silica refractories used for fixtures in brazing and heat treating applications North American Aviation Inc. (*Ind. Heat.*, 1960, **27,** Jan., 143–144) Fused silica refractories adapted for use in electric blanket brazing are Masrock, a slip-casting material fired at 2000 F, which has a 20000 lb/in^2 modulus of rupture and low coeff. of expansion; and Glasrock Foam, used as 4×18×18 in. blocks which have low density, expansion, and conductivity.—K.E.J.

New polycrystalline translucent ceramic for high temperature strength applications pressed to desired shape General Electric Co. (*Ind. Heat.*, 1960, **27,** Jan., 146–150) Polycrystalline Lucalox is made from powdered Al_2O_3. It combines translucence with high strength, heat resistance, and ease of fabrication. Fine-grain high-purity powder is pressed at room temp. and fired at higher temp. then normal to eliminate small internal pores or 'bubbles'.

The manufacture of zircon and fireclay-zircon refractory products J. Just (*Prace Inst. Hutn.*, 1959, **11,** (6), 297–310) After an examination of the physical properties and microstructure of pure zircon a method for the manufacture of crucibles is suggested. Details of the composition of the mix, the binder used, the drying temp. as well as of the die used are given. The influence of zircon sand additions on the quality of fireclay products is given. In particular preparation of the mix followed by the forming, drying, and burning of ladle nozzles is described. It was found that these nozzles were very resistant to changes of physical conditions during casting and that erosion of the nozzle orifice was negligible. With the correct shape these nozzles are particularly suitable for casting alloy steels at high temp., for casting of nozzle eroding steels, for steels which tend to scull up the nozzle orifice, for continuous and for top casting.

Magnesite crucibles for use in high frequency induction furnace M. R. K. Rao, P. C. Sen, and H. V. B. Rao (*NML Techn. J.*, 1959, **1,** Aug., 28–32).

Service life of refractory linings for the 500 ton open hearth furnaces V. G. Antosyak, Sh. M. Berman, and E. A. Ploshchenko (*Ogneupory*, 1960, (1), 24–30) The service life of the roofs of the 500 t OH furnaces may be increased by using magnesite–chromite and periclase–spinel refractories, by accurately controlling roof temp. by shortening hot repairs and maintaining the roof temp. during repairs to the hearth at a level not lower than the one prescribed. A number of other suggestions is also made.

Ladle bricks for electric steel manufacture. V. Some aspects on the characteristics of dinas bricks mixed with silicon carbide U. Ozawa and T. Yamada (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1959, **8,** Nov., 810–817) Studies were made to increase the erosion resistance of dinas bricks by addition of SiC powder. Bricks containing 50%SiC showed an erosion resistance of 5× that of the pure dinas bricks; this is attributed to the presence of a thick film of reaction products of the SiC with the slag.—T.G.

Research on the qualitative analysis of 3CaO·SiO$_2$ and βCaO·SiO$_2$ in dolomite refractories G. Yamaguchi, S. Tanaka, and Y. Niki (*Ann. Rep. Eng. Res. Inst., Tokyo*, 1959, **18,** Sept., 148–150) Stabilized dolomite refractories were analyzed by the X-ray method.

Research on super-duty insulating firebrick using high aluminous materials S. Nagai, G. Yamaguchi, Z. Ota, F. Tanemura, and M. Tsukino (*Ann. Rep. Eng. Res. Inst. Tokyo*, 1959, **18,** Sept., 151–153) Experiments in manufacture studied by using fine calcined bauxite for decreasing after-shrinkage at high temp.—S.H.–S.

Stress-strain-temperature-time relationships for refractory materials R. D. Chipman (*NAA–SR*–3205, 1958, Dec., pp.45; from *Nucl. Sci. Abs.*, 1959, **13,** March 15, 391) Creep tests are discussed and bend tests on BeO and SiC bodies were carried out from room temp. to 2730 F from a few sec. to 24 h. The method and results are evaluated.

Thermal expansion of silica refractories with relation to their mineralogical composition M. Starczewski (*Prace Inst. Hutn.*, 1959, **11,** (6), 311–317) The author found that the secondary expansion during heating of silica refractories is a good guide to the phase transformations that will take place on further heating. This is verified by the fact that the coefficient of secondary expansion obtained by experiment agrees satisfactorily with that obtained theoretically by considering the polymorphic changes of the quartz. In view of the high dimensional stability at a density of 2·33 gm/cm^3 the heating in the manufacture of coke-oven silica refractories should be such as to give a secondary expansion of 0·2–0·4% which corresponds to a density of 2·36 gm/cm^3. Attempts to reduce the density below 2·33 gm/cm^3 under industrial conditions are pointless in view of the high density of the impurities.

The causes for the disintegration of hot-blast stove and checker bricks made of fireclay S. Kienow (*Stahl Eisen*, 1960, **80,** March 3, 285–289) The mechanism of the disintegration of fireclay bricks in hot-blast stoves and checker works in particular structural changes occurring during service and the effect of alkalis and SO_3 was studied.—T.G.

Complex thermal analysis of Polish refractory clays S. Basinska-Pampuchowa (*Prace Inst. Hutn.*, 1959, **11,** (5), 235–249) Differential thermal analysis, thermogravimetric and dilatometric methods were used to analyse the structure of some Polish refractory clays. It was found that in the regions of Srzegom and Opoczno the main constituent was kaolinite though its structure varied with location. The author goes on to give detailed descriptions of the structure, composition, and impurities of the various clays. As for practical use of these clays it is found that livesite and interstratified clays—so long as they do not contain too much sand—show considerable plasticity and fire resistance. A very pure kaolinite structure means a drop in plasticity.

Rapid insulation of large diameter pipe at Inland Steel Co. (*Ind. Heat.*, 1959, **26,** Nov., 2344–2346) Mineral or slag wool insulation is supplied for piping up to 3 ft dia. in preformed 2 ft wide sections, with a welded galvanized wire as outer facing, fitted with rapidly secured lead wires and stay wires.—K.E.J.

IRON AND STEEL, GENERAL

Developments in metalworking and metallurgy during 1959 A. R. Putnam (*Ind. Heat.*, 1960, **27,** Jan., 48–54) A review, dealing with foamed metals, rare earths, making steel sheet from iron powders, vacuum degassing, high-strength steels, and alloys, Al vapour-coating, composite metals, Be and novel bonding techniques.—K.E.J.

Iron and steel production in the German Democratic Republic (*Iron Steel Rev.*, 1959, **3,** Dec., 31–34) A brief review of the rebuilding of the steel industry in the eastern part of Germany after the last war and of the progress made to accomplish the present seven-year plan.—T.G.

Profile of the American steel giant (*Times Rev. Ind.*, 1960, **14,** Feb., 6, 9, 10) The geographical distribution of the industry and output figures are given.

Towards a further rise in the iron and steel industry P. I. Korobov (*Stal'*, 1960, (1), 1–4) Progress with the seven-year plan is surveyed. Output and efficiencies of various plants are given. Various possible improvements are called for.

The Rourkela Iron and Steel Works in India H. Heinrich (*Stahl Eisen*, 1960, **80,** Feb. 18, 197–206) After reviewing the sources of raw material available for the new Rourkela iron and steel works the main plants are described including coke ovens, blast-furnaces, steelworks–OH and converter—oxygen plant, hot and cold rolling mills, etc.—T.G.

West plans integrated steel industry (*Canad. Metalw.*, 1959, **22,** Nov., 24–25) A symposium on the possibilities of developing the iron and steel industry of Western Canada is reported. Suitable reserves of ore and fuel are available. Smelting methods were surveyed; investigation is required to establish the most suitable.

Swedish steel mills are improving equipment (*Esso Oilways*, 1959 **10,** (3) 12–14) An illustrated account of the work of the firm of Morgardshammar.

Steel grows as Brazil grows (*Esso Oilways*, 1959, **10,** (3), 17–19) A brief account of Acos Villares S.A.

Chile is in the steel business (*Esso Oilways*, 1959, **10,** (3), 10–11) An account of the Huachipato Works.

Port Kembla's decade of development (*BHP Rev.* 1959, **36,** Oct., 14–17).

China's plan for steel R. Westgate (*Iron Steel*, 1959, **32,** Oct., 487–491) Chinese expansion programmes are discussed, with illustrations of some of the plant in production or under construction.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Durgapur's first blast furnace in operation (*Iron Coal Trades Rev.*, 1960, **180,** Jan. 15, 127–128) The first blast-furnace at the Durgapur steelworks, West Bengal, was commissioned at the end of December 1959. Two more blast-furnaces are being built.—T.G.

Amcor's new blast furnace (*Eng. Found.*, 1959, **25,** Oct., 49–50) Dimensions are given.

No.4 blast furnace: how a blast furnace works (*BHP Rev.*, 1959, **36,** Aug., 18–22) An account of the lighting of the Port Kembla furnace.

Port Kembla's new ore storage area (*BHP Rev.*, 1959, Dec., 27).

Lining the hearths of blast furnaces E. K. Keler and M. I. Bluvshtein (*Ogneupory*, 1960, (1), 17–23) A review of different raw materials available for the moulding of large lining blocks and of various suggestions put forward by a number of investigators.

Research programme on the blast furnace J. Cordier (*Rev. Mét.*, 1959, **56,** Dec., 369–374) An account is given of the IRSID programme on the use of a high proportion of sinter in the burden.

New techniques in the development of blast furnace production S. Kawiński (*Prz. Tech.*, 1959, **80,** (51), 7–9) Sorting and sintering equipment, though expensive, have a considerable effect on production and the capital outlay on the manufacturing capacity is reduced by 10%. The latest sintering belts, built at present in Poland, have a grate area of 75 m^2 and an output capacity of 900000 t per year. Artificial increase of the humidity of the blast and the introduction into the O_2 stream of coke oven gas and natural gas is also used.

Blast furnace is updated with nuclear stock gages Republic Steel Corp. (*Steel*, 1959, **145,** Oct. 12, 120, 124) An account is given of the development of a nuclear stock gauge employing seven radiation sources to determine both the level and distribution of the furnace charge. Ultimately the system may be used to control charging automatically.—A.G.

First gas turbine blower for blast furnaces passes final acceptance test (*Ind. Heat.*, 1960, **27,** Jan., 88) The Westinghouse turbine is cheaper in prime and operating costs, requires

less space, and uses practically no water. BF gas is burned, and the axial compressor will supply 125000 ft³/min. of air at South Works of US Steel Corp.

Modernization of obsolete furnaces in Poland by the adoption of the new selective. T. An. Tesch. System Charging Device W. Zolkowski (*Hutnik*, 1959, **26,** (11), 436–441) The author discusses the improved McKee's charging device which is used in Poland. Attention is drawn to the T. An. Tesch system which can give a greater saving in coke. The Tesch system solves the problem of making a seal between the stationary collar and the moving cone by introducing an additional cone and so giving a double seal. In addition, the Tesch system is distinct from all the others in that it enables the diameter of the collar which feeds in the charge to be changed.

Ultra-high-pressure blast furnace O. R. Rice (*Iron Coal Trades Rev.*, 1960, **180,** Jan. 1, 25–29) Development of an ultra-high-pressure blast-furnace with a top pressure of 40 lb/in², nearly four times that of any existing American blast-furnace, was recently announced in the USA. In the present account design features are described and illustrated and the economics discussed.—T.G.

Axial compressors D. Misárek and J. Šinták (*Czech. Heavy Ind.*, 1960, (2), 38–47) The principles of compression in axial compressors, their selection for particular applications and examples of such applications are described. The testing facilities of the ČKD Works, Prague, are included in the description. The compressors are used—*inter alia*—for blast-furnaces and gas turbines.—T.G.

New ore bridge runways and stockyard at Newcastle blast furnace plant L. W. Motum (*BHP Tech. Bull.*, 1959, **3,** Sept., 8–11) A general description.—S.H.-S.

Examination of the energy problems set in some British works by the development of charge preparation D. Sanna (*Centre Doc. Sidér. Circ.*, 1959, **16,** (9), 1977–1990) The effects of modern charge preparation and the use of sinter in coke quality and the thermal balance deficit are discussed with reference to a visit to four works in Great Britain.

The effect of improved coke quality on blast furnace performance. Twenty-sixth blast furnace conference W. Hunter (*BISRA publication*, 1958, 14–24) Data for Workington No.2 furnace are given, with general discussion. **Experience with self-fluxing sinter at the Steel Company of Canada** J. S. McMahan and J. W. Thomas (25–29). **The effect of sinter on furnace performance at West Hartlepool** R. W. Johnson (29–33, discussion 33–39). **The injection of materials into the blast furnace** E. W. Voice (40–43) Water, O_2, C, CO_2, H_2, air, lime, and iron ore are considered. **Effects of humidified blast** A. Grieve (44–47, discussion 47–51). **Some experiments in burden composition at Shotton** J. J. Evans (51–54). **Blast furnace practice at Ravenscraig** W. Banks (54–59). **The effect of burden composition on slag control and metal quality** J. W. Houghton (59–67, discussion 67–72).

Elementary consideration in the mechanism of fluids used in blast furnaces J. Le Floch (*Mét. Const. Méch.*, 1959, **91,** Dec., 897–911) Calculations relating to the regulation of blowers are presented. A mathematical study of blast-furnace profile. Injection of fluids other than those entering the normal cycle and dehydration or humidification of the air is also considered.

Lines on which work by IRSID in the blast furnace field is being directed J. Michard (*Rev. Mét.*, 1959, **56,** Dec., 363–368) Research is being carried out on improvement in coke rate and production. Factors affecting furnace running, in particular blast regulation, and thermal balance are being examined, taking into account the results obtained on the low-shaft furnace at Liège.

Clearing blast-furnace scaffold with dynamite M. P. Jourde (*Iron Coal Trades Rev.*, 1959, **179,** Oct. 30, 699–705) A report on the clearing of No.2 blast-furnace at Mandeville by lowering the stock line nearly to the bosh, luting up the furnace and blasting away the solid matter. The operation was carried out from 8–20 June 1957.

Flames and furnaces. The quality of energy M. W. Thring (*Iron Steel*, 1959, **32,** Oct., 483–485) The use of temperature/heat quantity diagrams in furnace design is reviewed, and the construction of a heat balance is described, and illustrated by examples taken mainly from blast-furnace practice.

The application of radioactive isotopes to blast furnace metallurgy J. Trau (*Hutnik*, 1959, **26,** (11), 431–436) The author discusses the use of radioactive isotopes in investigating the following processes inside the furnace: (1) The behaviour of the charge in the furnace; (2) The speed of gas flow; (3) The motion (speed and direction) of the separate components of the charge; (4) The deterioration of the refractory lining of the furnace during its operation. In Moscow a method has been evolved under laboratory conditions where the motion of the gases is observed by means of a mass spectrograph using inert gases rather than radon and so making the method cheaper.

The batch desulphurization of molten iron by the calcium carbide injection process R. B. Coates and J. V. Harding (*BCIRA J.*, 1960, **8,** Jan., 89–111) The CaC_2 injection process is described as well as the apparatus and equipment used. Numerous factors affecting the efficiency of the process are discussed and results obtained are summarized and presented in the form of graphs. Application of the process in industry is indicated.—T.G.

The rate and mechanism of the sulphurization of carbon-saturated iron L. D. Kirkbride and G. Derge (*Trans. Met. Soc. AIME*, 1960, **218,** Feb., 87–94) Transfer rate of S from slag to Fe–C was studied. Increase of Si, Mn, Ti, and Al retard transfer from 15%Al_2O_3, 45%CaO, 40%SiO_2 slag. MnO and FeO up to 4% have little effect. In certain ratios Mn in the iron and MnO in the slag increase transfer rates. The effective diffusion layer for Si in Fe was estimated at 0·025 cm. Si transport is proposed as rate-controlling step to preserve electrical neutrality in the slag phase.

Reduction of copper ferrite by graphite N. M. Stafeeva, V. N. Bogoslovskii, G. I. Chufarov, and V. A. Subbotina (*Doklady AN*, 1959, **128,** (6), 1210–1213) The mechanism of crystallochemical transformation in the reduction of copper ferrite may be presented as follows: As oxygen is removed, excess of iron and copper ions appear on the ferrite surface. The copper, with the weakest bonds with oxygen, forms a metallic phase and the iron diffuses into the ferrite particles after the copper has been displaced. The portion of tervalent iron changes into bivalent iron because of the reduction process and the ferrite lattice approaches that of the magnetite.

Some kinetic characteristics of the reduction of iron oxides by hydrogen S. T. Rostovtsev and A. P. Em (*Nauchn. Doklady Vyssh. Shkoly. Met.*, 1959, (2), 9–14) The cases of ore surrounded by a stream of gas and of an ore bed or column with gas passing through it are investigated and the derived kinetics are compared with actual findings. Degree of reduction over depth of bed at different temp., degree of reduction of portions of the bed at 400° and 800°C, effect of H_2 flow rate and H_2 consumption per 1% O_2 removal with rate of flow are considered.

The accelerating effect of potash on the reduction of magnetite by graphite S. S. Lisnyak and G. I. Chufarov (*Doklady AN*, 1959, **126,** (4), 831–833) In the reduction of metal oxides by solid carbon, reduction reactions occur also due to the CO and the gasification of the carbon by the CO_2, thus:

$$MeO + CO = Me + CO_2$$
$$CO_2 + C = 2CO$$

additions of alkali salts can speed up these reactions both as gaseous and as solid reducing agents. Experiments in which K_2CO_3 was added to the graphite and to the Fe_3O_4 with the ensuing reactions are described.

Calculation of the enthalpies of the direct reduction of iron oxides at high temperatures J. Maatsch (*Tech. Mitt. Krupp.* 1959, **17,** Dec., 343–344) The author discusses the laws of thermodynamics used in his calculation of the heat balance of the direct reduction of the iron oxides, FeO, Fe_2O_3, and Fe_3O_4. The calculations show clearly that the direct reduction is endothermic even at high temp. The results of the calculations are listed and presented in graphs.—T.G.

The reduction kinetics of iron ore by hydrogen and by hydrogen-methane mixtures B. Ilschner (*Tech. Mitt. Krupp*, 1959, **17,** Dec., 318–329) The stages at which a reduction of iron ore in streaming H_2 or in a mixture of H_2 and CH_4 at a temp. of 800°C proceeds were studied. It was found that the gases saturate very quickly with water vapour which makes them 'inert'. Increase in flow velocity overcomes this. Addition of CH_4 up to about 20% to the H_2 hardly alters the kinetics, although the reactions involved are different (25 refs.). —T.G.

The shaking ladle—a new metallurgical aid S. Edling (*Jernkont. Ann.*, 1959, **143,** (8), 487–507) The design, operation, and applications of this ladle are reviewed in detail. The ladle ensures thorough mixing of metal and of additions, and has been used for pig iron desulphurization (for which purpose it is said to be simpler to use than a conventional rotary furnace), recarburization, and pre-refining with O_2 to remove Si and V.

The mixing ladle, a new metallurgical tool S. Eketorp (*J. Met.*, 1960, **12,** Jan., 44–48) This ladle, developed by the Research Department of Stora Kopparbergs AB at Domnarvet, is rotated eccentrically; and produces thorough mixing of the metal and additions. Examples are given of its use for the desulphurization, recarburizing, alloying, and pre-refining of pig iron.

Ladle desulphurization of iron with lime and aluminium suspended in a gas S. K. Sobolev and G. N. Oiks (*Izvestiya VUZ Chern. Met.*, 1958, Nov., 3–8) An experimental apparatus giving 78% desulphurization has been built, consuming 1·8% lime and 0·03%Al based on wt. of iron. A method of blowing iron running out of the blast-furnace has been worked out; and the effect of Al was shown to be due to deoxidizing capacity, it does not remove S directly.

Improved blast-furnace gas cleaning S. A. Lewitt (*JISI*, 1960, **195,** June, 205–211) [This issue].

Influence of the nature of charge on the dimensions of low shaft furnaces B. E. Kitayev, V. A. Altekar, P. K. Sen, and K. K. Sarkar (*Trans. Indian Inst. Met.*, 1959, **12,** Dec., 323–332) A mathematical relationship is developed between particle size of charge, heat-transfer, kinetics of reduction and shaft weight which is divided into three zones. Values determined in conventional blast-furnace plant operation are used to calculate constants in the formulae derived. The subsequent calculation of the zone heights agreed with practice and the values therefore agree with low shaft practice.

Technical factors in the production of iron by methods other than the blast furnace J. Taylor (*J. West Scotland ISI*, 1960, paper No.523, p.10) Reduction by CO and solid C are discussed and the advantages of the blast-furnace are noted. Only shortage of suitable coking coal appears to limit its use. Problems arising with alternative processes are set out and increase of blast-furnace efficiency is held to make alternative processes of dubious utility.

The metallurgy of the reduction processes taking place in the rotary kiln: Development of a laboratory rotary kiln M. Wahlster (*Techn. Mitt. Krupp*, 1959, **17,** Dec., 330–342) Experiments are described for studying the reactions between ore and fuel in a novel research rotary kiln. Sieve analyses revealed the relation between grain size of the ore and the temp. in the furnace, whereas microscopy showed the structural changes occurring during the reduction, in particular the phenomena involved in the formation of metallic iron particles.—T.G.

Production of phenol from sodium phenates by blowing with blast furnace gas or with the combustion products of this gas M. I. Lyukimson (*Koks i Khim.*, 1959, (7), 59–60) In industry sodium phenates are decomposed with CO_2. The phenol yield attains 90%. In the regenerated alkalis there remains 2% of phenols with a NaOH content of 19–20%. The gas used in phenol plants for the decomposition of phenates contains up to 35%CO_2. In blast-furnace gas its content is 10–12% and in the combustion products 20–25%. A method is described of using this gas for the decomposition of the phenates in which the yield of

phenol amounts to 90%. Further experiments are necessary on a larger installation.

PROPERTIES, TREATMENT AND USE OF SLAGS

Activity of silica in CaO–Al_2O_3–SiO_2 slags at 1600 and 1700° C F. C. Langenberg and J. Chipman (*Trans. Met. Soc. AIME*, 1959, **215**, Dec., 958–962) New data on the distribution of Si between slag and carbon-saturated iron at 1600 and 1700° C are presented which permit the determination of the SiO_2 activities over a wide range of composition in the CaO–Al_2O_3–SiO_2 system. The actual values may be taken from isoactivity diagrams which are provided for the two temp.—T.G.

Kinetic factors in the reduction of silica from blast-furnace type slags J. C. Fulton and J. Chipman (*Trans. Met. Soc. AIME*, 1959, **215**, Dec., 888–891) The reaction mechanism, and its activation energy, was studied by which carbon in the coke or metal reacts with silica in the slag to deliver silicon to the metal. This reaction is very slow and never reaches equilibrium in blast-furnace practice. It is suggested that the slow reaction rate is associated with the breaking up of the Si–O bonds. The high heat of activation lends support to this view.—T.G.

Research on the activity of components in a fundamental system of iron blast furnace slag. II. Measurement of the activity of alumina in the system CaO–SiO_2–Al_2O_3 K. Sanbongi and Y. Omori (*Sci. Rep. Res. Inst. Tohoku Univ.*, 1959, **11**, (4), 339–351) [In English] Data were obtained for emf's of the cell Fe–Al–C_{sat}/CaO–SiO_2–Al_2O_3(I)/C or MgO/CaO–SiO_2–Al_2O_3(II)/Fe–Al–C_{sat} at 1630° C, and the activity of Al_2O_3 was deduced. On the CaO–SiO_2–Al_2O_3 diagram, iso-activity lines were obtained about the straight line between $2CaO.SiO_2$ in the CaO–SiO_2 system and the Al_2O_3 co-ordinate. These are interpreted in terms of anion species in the slag.—K.E.J.

Apparatus for determining the viscosity of boiler slag E. A. Galileeva and A. V. Krylova (*Teploenergetika*, 1959, (11), 85–88) The apparatus, used for the first time to determine the viscosity of boiler slags, is very simple, convenient in handling and as accurate as other existing instruments. The range of viscosity measured is the usual one for liquid slag removal and its operation may be fully automated.

The sulphur equilibrium between liquid iron saturated with carbon and lime silica slags H. Schenck, M. G. Frohberg, and T. El Gammal (*Arch. Eisenh.*, 1960, **31**, Jan., 11–17) The equilibrium conditions for sulphur were established between C-saturated iron melts and liquid lime–silica slags at 1550, 1600, and 1650° C, and were brought into relation with the basicity of the slag and the Si content of the iron. It is concluded that desulphurization should be attributed mainly to the reducing action of the carbon.—T.G.

Microscopical investigation of the crystallization of blast furnace slag L. Pardon (*Silikaty Sczasek*, 1958, **2**, 176–177) A series of photomicrographs in normal and polarized light, showing various stages in the crystallization of solidifying blast-furnace slag is reproduced, with a description of the structures developed.

Experiences with the foaming of metallurgical slags K. Säuberlich, J. Günther, and W. Koch (*Neue Hütte*, 1960, **5**, Jan., 12–21) Slag testing methods are reviewed and small and large-scale trials in the manufacture of 'pumice' slag are described and evaluated.

The utilization of blast-furnace slag in hot bituminous mixtures for road surfacing A. Send, G. Gelsdorf, and H. Kaiser (*Stahl Eisen*, 1960, **80**, March 3, 290–296) The structural requirements, such as grain size, porosity, etc., of blast-furnace slag for use in hot bituminous mixtures for road surfacing are described and studies are reported in which slags and various natural splits were compared in their characteristics and suitability for road surfacing. Roads subjected to heavy traffic and built with blast-furnace slag have stood up well to requirements.—T.G.

DIRECT PROCESSES

Methods of direct reduction of iron ore A. Roos (*Mét. Constr. Méch.*, 1959, **91**, Dec., 889–895) Various direct reducing processes in current industrial practice are described: Hoganäs, Wiberg, Stalling, H-iron and Udy, and a case is presented in favour of the Udy process.—S.R.–S.

Sponge iron in Mexico G. H. Muller (*Met. Progress*, 1960, **77**, Jan., 111–115) A description of the layout, operation, and costs of the HyL direct reduction process as worked at the Monterey plant of Hojalata y Lámina.

New electrical process for the direct reduction of iron ore A. de Sy (*Rev. Mét.*, 1958, **55**, Dec., 1161–1170) Direct reduction of iron ore is achieved in a twin-chamber mains frequency induction furnace consisting of a carburizing and a reduction chamber. Reduction is achieved by dissolved carbon. The economies, raw material requirements, and energy balance of a pilot plant are discussed.—R.P.

Some specific aspects of the Swedish steel industry J. Vidts (*ATB Met.*, 1959, **1**, (7), 201–205) Some characteristics of the Swedish steel industry observed by the author in a visit to a number of works are discussed and compared with Belgian practice. Particular reference is made to direct reduction processes.

PRODUCTION OF STEEL

The influence of oxygen on world steelmaking D. W. N. Pitts and J. L. Harrison (*Iron Steel*, 1959, **32**, Dec., 567–571) The use of oxygen in various converter processes, OH furnaces, and the electric arc furnace is discussed (25 refs).

The use of oxygen in combustion processes with particular reference to the steel industry T. C. Churcher (*J. Inst. Fuel*, 1960, **33**, Feb., 73–79, discussion 79–84; *Iron Coal Trades Rev.*, 1959, **179**, Dec. 4, 1007–1014) OH trials are reported and some Russian work is reviewed. Work with an oil burner and 100% O_2 is also described. A theoretical study and an account of laboratory experiments on a small furnace with a hearth of five copper calorimeters, water-cooled, are also included.

The importance of oxygen to progress in steelmaking T. Malkiewicz and K. Radzwicki (*Hutnik*, 1960, **27**, (1), 7–15) The motivation for the writing of this article was that the authors consider that it is unwise for Poland to fall behind in the development of the use of oxygen to replace air in steelmaking processes. The authors point out the advantages in so far as there is no heat carried off in waste nitrogen and the quality of the steel is not reduced by dissolved nitrogen. A description of the way that oxygen is being used in the OH and basic Bessemer processes in France, Belgium, Germany, and by the Steel Company of Wales is given.

Automatic control of steel production (*Elect. Times*, 1959, **136**, Oct. 29, 460) A review of BISRA studies on digital position control and electro-optical speed measurement.

Waste heat recovery units for metallurgical furnaces. I L. Stoicescu and C. Stamatescu (*Met. Constr. Mas.*, 1959, (9), 756–762) The first part of a study of the problem from a theoretical point of view.

Automatic control of production processes in iron- and steelworks S. Edling (*Jernkont. Ann.*, 1959, **143**, (8), 457–486) A large number of applications are discussed, with particular reference to data processing and various uses of computer control systems.

The modernization of the steelworks d'Imphy (*Ann. Mines*, 1959, Nov., 723–732) An illustrated account of the new equipment with special attention to the international suppliers of the plant.

Development of a Norwegian steel and wire works (*Wire Ind.*, 1959, **26**, July, 653, 659) A brief account is given of Christiania Spigerverk, a vertically integrated concern comprizing mines, pig-iron smelters, steelworks, rolling mills, and a range of factories manufacturing finished steel products.—A.G.

Durgapur Steelworks (*Elect. Rev.*, 1960, **166**, Jan. 8, 67) A note on the opening with a short account of the electrical equipment.

Small scale steelmaking D. L. Bryant (*Castings*, 1959, **5**, Nov., 9, 11, 13, 15, 17, 19, 21) A prize paper of the Australian Foundrymens Assoc. The reaction of molten cupola iron and oxygen in an acid-lined ladle to produce a castable mild steel is described. As little as 4 cwt can be produced and the major problem is control of S and P.

The pre-refining installation of the Maximilianshutte A.G. Ironworks in Sulzbach-Rosenberg J. Sittard (*SLA* 59–17928; from *Rep.*612 of a Committee of V.D. Eisenhuttenleute, 1955; pp.27; from *USOTS Techn. Trans.* 1959, **2**, Dec. 4, 820) A pre-refining blowing process of basic Bessemer iron is described.

Basic oxygen steelmaking installation at Fontana Plant of Kaiser Steel Corp (*Ind. Heat.*, 1959, **26**, Aug., 1563–1564, 1566, 1568) The plant and process are described, and the growing importance of O_2 steelmaking emphasized. The plant is rated at 1 440 000 t annually. The cycle time for the production of 100 t of steel is 1 h, the refining time 30 min., and 6·1 t of O_2 are required.

Oxygen steel passes its tests: more, bigger units planned G. J. McManus (*Iron Age*, 1959, **184**, Sept. 24, 67–68) Projects are described which will raise the annual output of oxygen steel to 10^7 t by 1962. This development is centred on the LD process which is being modified to permit a higher proportion of scrap in the charge.—A.G.

The basic oxygen process, Jones & Laughlin Steel Corporation D. R. Loughrey (*Iron Steel Eng.*, 1959, **36**, Dec., 110–116) The layout, capacity, operating data, and results obtained with the LD plant at the Aliquippa Works of Jones & Laughlin Steel Corp. are described and reported. The plant went into operation in September 1957. Satisfactory quality low P and N steel is made in low and medium C grades.

Effect of the slag on the basic refractory lining of converters blown with oxygen I. I. Korobov, S. B. Gol'bets, and E. V. Ivanov (*Ogneuporg*, 1959, (11), 510–517) A study of the erosion of the refractory linings is reported without any definite conclusions except to continue investigations for perfecting the construction of converters and the production of bricks and of refining the iron in the mixer to reduce the silicon content.

Comment on the report by H. Beck: 'Contribution to the metallurgy of the Thomas process' P. Leroy (*Centre Doc. Sidér. Circ.*, 1959, **16**, (9), 1991–1996) The author comments on points raised in Beck's paper dealing with blowing capacity and the effects of iron temperature and coolants.

Handling of lime and scrap Bochet (*Centre Doc. Sidér. Circ.*, 1959, **16**, (3), 639–643) Details of the equipment installed for handling and charging these materials into the Thomas converters at Providence (Rehon) are given.

Application of physical chemistry to the basic oxygen steelmaking process A. Decker and P. Metz (*Centre Nat. Recherches Mét. Liège*, 1959, reprint, pp.12) [In English] An examination of the LD process with data for other steelmaking methods. The kinetics of the various processes of oxidation and S and P removal are discussed. The conclusions generally confirm previous conceptions (32 refs).

New developments in iron- and steelmaking due to reactions obtained between pulverized materials and liquid metals M. Allard (*Ind. Nationale*, 1959, (3), 41–47) The development by IRSID of the OLP process in which powdered lime is injected into the converter blast is described, and some operational data and results are reported.

Belt conveyors transport additions to a height of 43·5 metres K. Wagner and E. Schmidt (*Hüttenzeitung Bochumer Verein*, 1959, **29**, Feb.–March, 2–5) A bunker and conveyor system is described by which the oxygen steel plant of Bochumer Verein is supplied with the necessary ore and fluxes, which are charged in the correct amounts and proportions.

Refractory materials in the light of the progress made in steel making K. Radzwicki (*Hutnik*, 1959, **26**, (11), 441–443) In connexion with the constant progress in the field of steel production the quality and efficiency of furnace linings must be improved. The requirements of various processes are discussed. In connection with the proposed manufacture of O_2 steels the construction of tuyeres should be made more durable. In the degassing of fluid steel *in vacuo* in the USSR corrosion of plug-

rods was eliminated by using rods of high Al_2O_3 content.

The oxygen lime spray process for refining pig iron B. Trentini and M. Allard (*Iron Steel Rev.*, 1959, **3**, Sept., 37–40) The 'OLP' process for refining pig iron developed by IRSID in France is described. The process involves blowing O_2 and powdered lime on to the molten metal in a converter. It has the following characteristics: refining any type of pig iron to the required grade of steel; long life of converter basic lining; product has low P, S, and N_2 contents; has been operated on scale of 30 t charge; low cost.—D.L.C.P.

Study of some converter bottoms with copper tubes J. Kuhnast (*Centre Doc. Sidér. Circ.*, 1959, **16**, (3), 645–649) The results of trials described show that an increase of 15–20 heats in converter bottom life was obtained by the use of Cu tubes.

Steelmaking by the LD process with cooling by addition of ore K. Grunberg, W. Schleucher, and R. Kunz (*Stahl Eisen*, 1960, **80**, March 3, 277–281) The authors describe the LD process as it is used at the Bochumer Verein, i.e. with cooling by addition of ore instead of the usual scrap. The advantages of using ore for cooling are discussed in detail, and the metallurgy of the process is explained. It is claimed that the steel produced by this process is—for certain applications—superior to OH steel owing to its low content of impurities, H_2 and O_2. In an introduction to this paper, the Editorial Board of *Stahl u. Eisen* defines the terms under which the various steelmaking processes in which O_2 is blown on to the bath should be known and outlines their field.—T.G.

Contribution to the metallurgy of the LD process E. Plockinger and M. Wahlster (*Tech. Mitt. Krupp*, 1959, **17**, Dec., 295–305) The theory of the LD and similar processes is discussed and a small, 3-t capacity converter described with the aid of which the metallurgical reactions taking place in current industrial practice, i.e. with ore, scrap, and limestone-split cooling was studied. The reaction equilibria—which compared with the OH furnace are very much out of balance during the actual blowing time but are attained surprisingly quickly afterwards—were investigated.—T.G.

Material and heat balance of the LD process J. Maatsch, E. Plockinger, and M. Wahlster (*Tech. Mitt. Krupp*, 1959, **17**, Dec., 310–317) Material and heat conversion during the processing of a 3-t LD heat was calculated on the basis of experimental findings. The results are presented in tables and graphs; they give an interesting insight into the reaction processes and show the strong fluctuation of heat supply and heat consumption during refining.—T.G.

Economic considerations on the choice of the raw materials for the charge of open-hearth furnaces G. Schmidt (*Stahl Eisen*, 1960, **80**, March 3, 282–285) The economy of an OH steel plant that has to buy all its pig iron—mostly in liquid form—is discussed.—T.G.

The aerodynamic approach to furnace design J. H. Chesters (*Trans. ASME, J. Eng. Power*, 1959, **81A**, Oct., 361–370) Studies in flow patterns and droplet dynamics with reference to OH furnace design are considered (25 refs).

Investigations and control of open hearth production problems A. V. Lang and T. A. Cleary, jun. (*Ind. Heat.*, 1959, **26**, July, 1374–1386) A number of examples is quoted to illustrate statistical methods of determining optimum factors and eliminating unwanted conditions. For a particular furnace, recommendations for optimum practice concern frequency of washing chequers, charge times, and heat times, and heat time in terms of progress of the campaign.—K.E.J.

Ajax inhales oxygen (*Economist*, 1959, **193**, Nov. 28, 885–886) A non-technical note on O_2 blowing of OH furnaces at Appleby-Frodingham.

Report of the working group of the open-hearth committee: 'Influence of charge preparation and rate of charging on melting rates' E. Puton (*Centre Doc. Sidér. Circ.*, 1959, **16**, (9), 1997–2017) The investigation was divided into two series, i.e. with or without modification of the charge. In the first category, it was concluded that there exists for each rate of firing an optimum charging rate; various measures for increasing charging rate are reviewed. In the second series, the influence of varying the proportions of solid and liquid iron in the charge, and the effects of the proportions of primary metal and heavy scrap, and other factors are discussed.

Open-hearth steelmaking Committee. Meeting held 20 21 Dec. 1957 (*Centre Doc. Sidér. Circ.*, 1959, **16**, (3), 679–684) A résumé of papers and discussions of the Energy Conference held on 11 Dec. 1957, a report of the Flame and Industry Symposium held in London on 9 October 1957, and of the Working Group 'Furnace Construction'.

Innovations for prolonging service of open hearth refractories. II A. J. Voss (*Ind. Heat.*, 1959, **26**, Dec., 2535–2540) A hot-patching technique for OH roofs was developed from the use of silica veneer bricks; to overcome spalling and eliminate keying troubles, a tabbed basic metal-encased brick was designed. To deal with increased firing rates in checkers, the five top courses were laid with chrome magnesite or magnesium silicate bricks, which gave excellent results.—K.E.J.

Progress with basic roofs for open hearth furnaces. II (*Ind. Heat.*, 1959, **26**, Nov., 2333–2342) Detailed operating data are given for furnaces at Laclede Steel Co., Inland Steel Co., Granite City Steel Co., US Steel Corp. (South Works), and Armco Steel Corp.

Operational experiences with a steel-tube recuperator H. Rheinfeld (*Iron Coal Trades Rev.*, 1960, **180**, Jan. 8, 63–65) The principle of the steel-tube recuperator designed by Schack of Germany is described and experiences gained at various plants in Germany are reported. This design has the advantage of giving a blast of very uniform temp. which may be as high as 800°C.—T.G.

A study of deposition and carry-over of melting dust in steelmaking furnaces, using a scale model M. A. Glinkov and A. L. Serokhvotov (*Nauchn. Doklady Vyssh. Shkol. Metallurgiya*, 1959, (2), 84–88) A methyl methacrylate model of an OH furnace (30 t) was constructed and dust deposit pattern and carry-over were examined. Flame reversal and recycling conditions and regenerator and recuperator lives are considered. Application to the LD process is discussed.

A primer on deoxidation C. E. Sims and C. W. Briggs (*J. Met.*, 1959, **11**, Dec., 815–822) Mechanism of the deoxidation of steel is reviewed, the characteristics of various deoxidants are described, including complex deoxidizers, and the question of the formation of inclusions is considered. The tendency of high N_2 contents to cause porosity, and results of deoxidation trials on high N-steels are outlined.

BISRA. Electric steelmaking and the economics of large arc versus open-hearth furnaces (*Fifty-first steelmaking conference, Leamington Spa*, 1958, Sept., pp.49). **Introductory remarks on the electrical aspects of electric arc furnace operation** J. R. Phillips (5). **The determination of the electrical characteristics of an arc furnace** J. Ravenscroft (6–12) **The electrical characteristics of a 30-ton electric arc furnace** E. M. Greaves (12–17). **The effect of circuit reactance on arc furnace performance** J. Ravenscroft and D. B. Copley (17–23). **The effect of voltage and power input on the performance of a 3-ton arc furnace** J. Ravenscroft (23–28). **Heat transfer investigations and the development of the automatic control of power input on the BISRA 10-cwt arc furnace** J. Ravenscroft and L. McGee (28–32, discussion 32–35) With appendix on the programme controller for regulating arc furnace power input. **Arc investigations on the BISRA 10-cwt furnace** D. B. Copley (35–37, discussion 38–39). **Alloy steel production in the large arc furnace** F. T. Bagnall (39–41). **Plain carbon steel production in large arc furnaces with special reference to the economics as compared to open-hearth steel production** R. S. Howes (41–45, discussion 45–48).

Desulphurization of basic electric arc furnace steel by the injection of powdered materials L. Marples and J. Pears (*JISI*, 1960, **195**, June, 195–201) [This issue].

Arc furnaces for largest electric steel plant United Steel Co. (*Elect. Times*, 1960, **137**, Jan. 21, 99) Plans for replacing 21 OH furnaces with six large steel furnaces are noted.

Bulk production of steel in electric arc furnaces F. S. Leigh and J. B. Ingall (*BEAMA J.*, 1959, **66**, Nov., 129–133) An illustrated account of furnace design and performance.

Design and operation of an 80-ton electric furnace in Russia L. S. Katsevich (*Iron Coal Trades Rev.*, 1960, **180**, Jan. 15, 137–139. Translated from *Metallurg.*, 1959, Sept.).

Control of the operation of an electric furnace B. V. Semenovich (*Promyshel. Energ.*, 1959, (10), 22–24) A control scheme is described for modifying the connexions of the instruments which makes it possible to measure not the line current but the currents passing through the phase windings of the transformers. The secondary windings of the transformers are not connected star-fashion but in a delta network.

Automatic control of the current to the electrical arc furnace A. I. Alixanyan, V. S. Chichikanov, and M. G. Miridzhanyan (*Promyshl. Energ.*, 1959, (11), 8–10) The scheme of automatic control has the following advantages. Single phase control; interchangeability; rapid action; displacement of electrode is carried out to the different speeds proportional to the deviation of current and voltage or to either of these factors; it can be replaced by manual control in case of need and the scheme is simple and does not require special or constant supervision.

The development of arc steelmaking furnaces and of electrode control mechanism A. Driller (**Electrotechnische Z.*, 1956, Feb. 21, 41–47) The development of large electric arc melting units is outlined, and the design and operation of modern hydraulic and electromechanical control mechanisms are described.

Experience with electric arc furnace controls H.-J. Forst (*Elektrowärme*, 1959, **17**, July, 260–265) Particular reference is made to the use in Germany of electro-hydraulic electrode control systems. Their operation and limitations are discussed.

An estimate of the properties of an electric arc furnace with the aid of the current indices method T. Schwartz (*Archiwum Electrotechn.*, 1959, **8**, (2), 301–312) Conditions corresponding to minimum consumption and maximum throughput are examined. A nonogram for maximizing the relationships is given.

Arc furnace transformers C. R. Hatch (*Elect. Rev.*, 1960, **166**, Jan. 8, 52–56) With the growth of electric furnaces problems of the transformer are raised. These are discussed with illustrations and diagrams with special reference to core and windings and secondary voltage variation, tap changing, p.f. correction, and cooling.

Inductive stirring in arc furnaces E. Hammarlund and B. Hanas (*Iron Coal Trades Rev.*, 1960, **180**, Feb. 5, 299–307) The principle and results are surveyed. Homogenizations of composition and temp. and effects during oxidation and deoxidizing, and effects on S and Cr, slag removal and lining wear are considered and economies affected are indicated.

Practical economics for stainless steel melters R. B. Shaw (*J. Met.*, 1959, **11**, Dec., 823–828) It is shown how economies are possible in electric furnace practice by ensuring the correct charge and improving melting procedures so as to improve yields.

Acme Steel inaugurates novel steel mill operation in the United States (*Iron Steel Eng.*, 1959, **36**, Aug., 129) The use at the new Riverdale, Illinois plant of Acme Steel of a steelmaking technique using a combination of continuous hot blast cupolas and top-blown oxygen converters is outlined.

Automated ladle additions up steelmaking efficiency Blaw Knox Co. (*Steel*, 1959, **145**, Sept. 14, 172, 176) The ladle additions feeder described consists of one or more storage hoppers, and electronic weighing system based on load cells and a vibrating feeder. The system is said to save labour and to economize Mn, eliminate freezing and separation, and reduce the spread in Mn content from first to last ingots.—A.G.

Covers on hot tops save steel (*Iron Age*, 1959, **184**, Aug. 6, 92) The use of special hot top covers is said to increase yields by 1½%. The cover consists of a top layer of insulating material, a steel separating plate, and a bottom layer of non-carbonaceous exothermic

material packed in a heavy cardboard container.—A.G.

Rimming steels for telegraph wire cast in bottle-shaped ingot moulds N. F. Dubrov (*Stal'*, 1960, (1), 44) A note from the Urals Sci. Res. Inst. for Ferrous Metals. A smooth surface is obtained, no mould dressing is needed and cover plates are unnecessary when 120-t melts are cast into 250 kg ingots in these moulds. With smaller crop ends the yield is 4–8·5% higher.

Vallak hot top improves world steel yield (*Iron Steel Rev.*, 1959, **3,** Dec., 35–37) The advantages offered by the use of the Vallak hot tops in ingot steel castings are briefly described.—T.G.

Ultrasonic control of grain size in austenitic steel N. V. Khimchenko and V. N. Prikhod'ko (*Zavods. Lab.*, 1959, (7), 836–839) Grain size control in steels, non-ferrous metals and alloys may be achieved by means of very high ultrasonic frequencies. Special apparatus has been constructed which is here described with block and circuit diagrams.

Camera study of the behaviour of splash cans during teeming M. Jones, T. D. B. Hughes, and C. W. Latty (*Iron Coal Trades Rev.*, 1959, **179,** Dec. 11, 1063–1065) The method used and some of the photos are given. The cylindrical can was shown to be superior to the rectangular and with small modifications the former has proved effective.

A machine for twin-strand casting of square-section ingots P. I. Mitrofanov, Kh. L. Kaplan, A. N. Grigor'ev, M. N. Vysotskii, A. N. Shabanov, G. R. Korotkov, and A. S. Kaushanskii (*Stal'*, 1960, (1), 43–44) A redesigned system for continuous casting with mould, cooling system, withdrawal stand, dummy bar, and auxiliary stand for removing the dummy bar and flame cutting without danger of the bar slipping or being distorted to diamond shape by pressure is described.

Thermoelectric method of measuring the metal surface level in continuous casting A. Elkershausen (*Neue Hütte*, 1960, **5,** Jan., 31–36) The method described depends on the measurement of the rise in temp. of the mould wall, and has been used in a three-strand plant for several months. The possibility of combining the measuring equipment with a system for automatic control of metal level in the mould is discussed.

Experiment in the use of pouring basins for the continuous casting of steel V. N. Strelets and I. N. Pitak (*Ogneupory*, 1960, (1), 30–32) These are clay-graphite pouring basins with a boring to take a magnesite lining. A specification for materials and for construction is given.

The service life and alteration in the phase composition of the stoppered funnels in continuous casting of steel L. A. Kuz'mina, N. V. Pitak, and V. M. Sterlets (*Ogneupory*, 1959, (12), 560–566) The corrosion of the funnels is due mainly to the action of the slag forming a large amount of a glass-like substance, anorthite, magnesium spinel, etc. The burning of the stoppers is due mainly to contact of the liquid metal with the metallic core of the stopper through the cracks. The greatest resistance is shown by high-alumina-lined funnels.

FOUNDRY PRACTICE

Metal yields in the foundry A. Mal (*Fond. Belge*, 1960, **30,** Jan., 17–18) Formulae are given for various types of casting.

Consumption of raw materials in the foundry M. Martin and F. K. Garman (*BCIRA J.*, 1960, **8,** Jan., 67–88) This is a report issued by the Foundry Operations Section of the BCIRA on information collected about the consumption in foundries of coke, limestone, ganister, pig iron, and new moulding sand. The presentation is in tables and graphs and the findings are discussed.—T.G.

Save by spending on mechanical handling equipment. II H. W. Zimnawoda (*Canad. Metalw.*, 1959, **22,** Nov., 44–45) Mechanized foundry handling equipment is described.

Gas—foe or friend of the foundryman N. L. Bush (*Castings*, 1959, **5,** Sept., 13, 15, 17, 19, 21, 23, 25, 27, 29, 31–33, 35) Work on blowing with O_2 is described. At low pressures Si and Mn can be largely removed without much change in C, higher pressures also remove the C. Faults, pinholes, inverse chill and gas evolution effects, are also discussed.

South Africa's most modern steel foundry Scaw Metals Ltd (*Eng. Found.*, 1959, **25,** Sept., 34–43) An illustrated account of the planning, layout, and equipment of the foundry.

Dominican Republic's first foundry Astilleros Dominicanos C. por A. (*Foundry Trade J.*, 1960, **108,** Jan. 14, 47–47) The foundry at Haina is briefly described.—T.G.

Would a basic cupola be beneficial to all foundries? I. R. Duncan (*Eng. Found.*, 1959, **25,** Aug., 39–41) The advantages of the cupola of this type are indicated and outstanding questions are noted.

Methods of heating the cupola blast R. Woznacki (*Prz. Odlewn.*, 1960, **10,** (1), 9–15) A classification of cupolas with heated blast is given and the advantages of the scheme are discussed. An experimental installation is described and its advantages can be summarized as follows: (1) Simple construction; (2) The simplicity of adaptation; (3) Simplicity of operation; (4) Distinct technical and economic advantages with blasts in the region of 400°C.

Metallurgical coke in a small cupola A. S. Tsynovnikov, V. B. Shemeryankin, S. A. Shvarts, K. A. Bogoyavlenskii, and A. I. Tolochko (*Koks i Khimiya*, 1959, (11), 30–34) This refers to the GOST 8929–58 specification which as from the 1 March 1959 became operative, and to the investigation of its use in the small cupola. The different origins with characteristics are listed.

Desulphurization of cupola cast-iron by tuyere injection of calcium carbide D. H. Eastwood and D. W. N. Pitts (*Found. Trade J.*, 1960, **108,** Jan. 28, 99–102) Work is reported showing that iron can be produced with $<0{\cdot}008\%$S by injecting CaC_2. The fall in S is accompanied by a rise of C of 0·2–0·5%.

Oxygen aids for the cupola Commonwealth Industrial Gases Ltd (*Castings*, 1959, **5,** Aug., 9, 11, 13, 15) The use of the oxygen lance for lighting up and the effects of enrichment by 0·5–1% with occasionally 3–7% from cylinders are described. Also the use of O_2 for clearing tap-holes and blowing in the ladle are briefly mentioned.

Methane gas used for melting cast iron in the cupola C. Stefanescu, T. Steflea, and S. Teodoreseu (*Met. Constr. Masini*, 1959, (8), 671–682) Experiments are described of a normal 500 mm cupola being altered with a second row of tuyeres through which CH_4 is supplied for combustion in a fixed ratio to the air blast. The first results under industrial conditions have proved satisfactory.

Melting and melting equipment in the iron foundry (*Bradley's Mag.*, 1959, Autumn–Winter, 4–5, 7) The cold and hot blast cupolas, electric, and rotary furnaces are discussed.

More steel with oil (*Esso Oilways*, 1959, **10,** (3), 19) The use of oil firing at Samuel Fox & Co., Stockbridge, is mentioned.

Tilting rotary furnaces (*Edgar Allen News*, 1959, **38,** Dec., 274–275) An illustrated account of the Stein & Atkinson design.

The manufacture of spheroidal graphite cast iron in the cupola forehearth J. Taran and M. Swiech (*Prz. Odlewn.*, 1960, **10,** (1), 27–30) Since 1953, attempts to introduce Mg into the melt at the PZBU works in Bydgoszcz have finally resulted in the method used for the last three years being adopted. This method is based on the introduction of Mg electrodes into the cupola forehearth. The method, its operation and castings made to date are described in detail. It was found that the time taken to introduce the Mg has been reduced. Furthermore the temp. drop of the melt has also been reduced.

The circuitry and operation of induction furnaces G. W. Seulen (*Elektrowärme*, 1960, **18,** Jan., 1–13) The circuitry of low- and medium-frequency melting and holding furnaces are given and the advantages of a combination of two or more furnaces on the power factor and current utilization pointed out. The effect of superheating on the preservation of the nuclei in the melt is discussed in detail.—T.G.

Induction melting in mains frequency or medium frequency crucible furnaces? K. H. Broknieer (*Elektrowärme*, 1960, **18,** Jan., 13–20) The author compares the advantages offered by mains and by medium frequencies for the induction melting of iron and steel. The aspects involved are discussed in detail. Although the medium-frequency plant is the more expensive of the two, it offers so many advantages with respect to operation and to the metallurgy of the product that the author is in favour of employing it.—T.G.

Induction and resistance melting furnaces: Introduction F. Sommer (*Elektrowärme*, 1959, **17,** Oct., 355). **Applications and economy of medium-frequency induction furnaces** K. Schäfer (355–360) Design and operation, the relation of size to frequency, construction and refractory lining, and the advantages of medium-frequency furnaces are reviewed. **Operating experience with medium-frequency induction furnaces** G. W. Seulen (361–366) Two large furnaces are described and operations with cold and duplex charges, economics, and advantages are considered. **The low-frequency ring-induction furnace design, applications and economy** J. P. Rohn (367–372) Mostly non-ferrous but a cast-iron melting furnace is included. **Operating results of resistance furnaces for melting steel, cast iron, light and heavy alloys** F. Deutz (373–376) The graphite resistance furnace has special uses, vacuum degassing using graphite rods has proved effective.

A technique for the melting and heat-treatment of soft magnetic alloys N. F. Dubrov (*Stal'*, 1960, (1), 50) A note from the Urals Sci. Res. Inst. for Ferrous Metals. Effects of repeated remelting in an arc-furnace on 50N and 79N5M alloys have been studied. Melting three times increases permeability 1·5 to 2 times and reduces coercivity. Vacuum melting has effects depending largely on the subsequent annealing.

Arc-furnace melting J. A. Charles and A. G. Cowen (*Iron Coal Trades Rev.*, 1960, **180,** Feb. 12, 353–358) Work on the injection of gases through hollow electrodes on a 1-cwt furnace is reported. A, N_2, coal gas, H_2, and CO were used at 1 ft³/min. Only argon had any significant effect, but this reduced melting time 22% and decreased power consumption 13%.

Convert chips into castings (*Iron Age*, 1959, **184,** Dec. 31, 50) A new induction melting unit, the 'Multiductor' is ideal for reclaiming chips, turnings, and borings. A static device generates the 180 cycle current so that the unit can be installed in a foundry without trouble from moving parts.—D.L.C.F.

Arc furnace installed at Ferranti factory (*Elect. Rev.*, 1959, **165,** Dec. 4, 786) A furnace for producing cast iron from scrap is described.

Ferranti Ltd. produce pig-iron from scrap steel (*Foundry Trade J.*, 1960, **108,** Jan. 28, 107–108).

Electrical firm recovers steel scrap (*Elect. Times*, 1959, **136,** Dec. 3, 674) An arc-furnace at Hollinwood is briefly described.

Effect of rare-earth additions on some stainless steel melting variables R. H. Gautschi and F. C. Langenberg (*Trans. Met. Soc. AIME*, 1960, **218,** Feb., 128–132) Type 310 stainless was treated with rare earth metals to observe the effects on as-cast structure, N and S content and non-metallic inclusions. La has a grain-refining influence on small ingots but on 200 lb ingots the effects were inconsistent. Ce, La, and mischmetal lowered S where this was >0·015% with additions of >0·1%. Non-metallic inclusions did not change in 30 lb ingots but had some effect in larger ingots.

Sand castings (*Castings*, 1959, **5,** Aug., 17, 19) An economic survey of trade, stocks, and employment.

The origin and significance of grain structure in sand castings V. Kondic (*Brit. Found.*, 1959, **52,** Dec., 542–549) Information dealing with the origin, shape, and size of grains in cast alloys is reviewed and its significance in the manufacture of castings is discussed.—A.D.H.

An effect of phosphorus on the solidification expansion and soundness of nodular graphite irons K. E. I. Nicholas (*BCIRA J.*, 1960, **8,** Jan., 29–38) The addition of P to nodular graphite cast iron results in severe shrinkage and in exceptionally large casting solidification

expansion. Deep etching shows that the phosphide eutectic exists as a continuous network surrounding the austenite-graphite eutectic cells. A theory is put forward which tries to explain the great solidification expansion and unsoundness of nodular graphite cast irons containing P.—T.G.

Manufacture and properties of s.g. iron G. Skiffington (*Eng. Found.*, 1959, **25,** Sept., 55–57) Practice at James Barwell (S.A.) Ltd, Alberton, is outlined. Properties of the material are noted.

S.G. iron in steelworks plant A. D. Everest (*Mond Nickel Co. Circ.*, 1959, pp.22) An account with illustrations of the use of s.g. iron in coke ovens, sinter plant, blast- and steel-furnaces, casting and rolling shops, and miscellaneous uses.

Ladle inoculation of high quality grey iron A. Somigli (*Fond. Ital.*, 1959, **8,** Dec., 445–448) The use of graphitizing inoculants, usually based on silicides, is described, and detailed results are given. Main advantages as to finished product are improved workability and fewer defects. Greater flexibility and lower costs in production result as by later addition of graphitizing elements iron of varying qualities can be obtained from the same initial burden.

'Ni-hard' A wear-resistant cast iron A. B. Everest (*Maschinenwelt Elektr.*, 1960, **15,** March, 75–79) Properties and applications, particularly in the mining and cement industry, of the so-called Ni-hard cast iron are reviewed. Ni increases the hardness of cast iron up to level of about 4·5% by gradually changing the pearlitic structure to a hard martensite that has the desired wear resistance.—T.G.

Study of a high-chromium martensite cast iron A. Vilain and J. Marlot (*ATB Mét.*, 1959, **1,** (7), 183–191) Assessment of the results of an experimental study of Ni–Cr alloy cast irons containing 2–14%Cr indicates that alloys with 5·5%Ni and 5·5–6·5%Cr give a eutectic iron with a martensitic structure, with high hardness and comparatively low brittleness. Possible applications of the alloy are discussed.

Are all-black malleable and white-heart malleable two different materials? H. Lehmann (*Giessereitech.*, 1960, **6,** Jan., 19–20) In Germany white-heart malleable is usually produced whereas outside Germany all-black malleable is preferred. The author compares the properties of the two types of metal and advocates the dropping of the names of the material and quotation simply by the mechanical strength values which are rather similar.

Edgar Allen steel castings (*Edgar Allen News*, 1959, **38,** Dec., 265–268) The foundry and its equipment are described.

Steel founding with zircon sand (*Eng. Found.* 1959, **25,** Oct., 50) Use at Livingstone, near Victoria Falls, is briefly described.

Steel castings for high duty H. E. Hübscher (*Met. Prog.*, 1960, **77,** Jan., 77–81) Manufacturing, inspection, and machining methods at the steel foundry of George Fischer Ltd., at Schaffhausen, Switzerland are described. Large castings up to 45 t are made for turbines, electric generators, large diesel engines and aircraft, and the steel is produced in electric-arc furnaces.

The casting of steel supporting pedestals with a cast weight of 10·5 tons using exothermic sleeves W. Longa and S. Strama (*Prz. Odlewn.*, 1960, **10,** (1), 23–27) The old method and that using exothermic sleeves are described. It was found that when exothermic sleeves in the riser were used not only was it possible to make a 10·5 t casting from two furnaces with a maximum output of 6·5 t, but the cost was reduced. Shrinkage cavities were observed on the first few castings. This was put down to too early an ignition of the sleeve. After an insulating coating had been applied to the inside of the sleeve, in order to delay ignition, no cavities were noticed.

First steps for standardization of the steel castings production H. Pfeiffer (*Giessereitech.*, 1960, **6,** Feb., 45–46) This is a report of a meeting attended by representatives of the Government's planning commission, of the management of the people's own works, and of the people's own steel castings works on the standardization of steel castings in the German Democratic Republic. In conformity with the requirements made by the Socialist Party's Secretary, Walter Ulbricht, each works will in future restrict the number of steel compositions employed and will also be more specialized than hitherto. This will show that the steel casters are no longer a hindrance in the development of the nation's economy.—T.G.

On the spheroidization of the carbide phase in steel B. S. Kazarnovskii (*Fiz. Met. Metallov.*, 1959, (5), 703–707) The findings of the investigations show the great influence which the rate of cooling from 700–600° has on the rate of spheroidization of the carbide phase. In slow cooling within this range, the diffusion path of the carbon is shortened. This is due to the more complete elimination of carbon from the α-phase as highly dispersive carbides. It is therefore possible to envisage conditions for obtaining fine-grain pearlite, especially in alloy steels, by selecting optimum conditions of cooling between 700 and 600°.

Cast-steel wheels for railway trucks D. S. C. Fraser (*Found. Trade J.*, 1960, **108,** Feb. 4, 131–134) An account of the new Griffin Steel Foundries plant at Manitoba.

Cast stainless fittings for oil plant headers combine corrosion-resistance, casting design advantages (*Western Metalw.*, 1959, **17,** Nov., 56) The steel contains 18–21%Cr, 8–11%Ni, and >0·08%C and is used for header bodies in the processing of California crudes which contain S and other corrodants that cause C steel to corrode at a very high rate. These cast stainless steel header bodies have given years of trouble-free service at fluid pressures of 450 psi and temp. of 900°F.—T.G.

Experience gained in pneumatic transport of sand O. Persson (*Giesserei*, 1960, **47,** Feb. 11, 68–70) The reasons for the choice of a pneumatic sand transport system for a Swedish foundry are discussed and the plant and its maintenance described. Operation and maintenance costs are very low.—T.G.

Preparation and classification of foundry sands by washing T. Eder (*Giesserei*, 1960, **47,** Feb. 11, 62–68) Various types and methods of washing and classifying foundry sands are described including the recovery of used sands. The advantages offered by vertical washing and classifying methods are stressed.—T.G.

New study of the behaviour of fire-clay and silica sand for steel castings A. Völpel (*Giesserei*, 1960, **47,** Feb. 11, 56–62) The author studied the metal/mould reactions as a function of sand composition and ramming strength and points out the effect of mould dressings on the penetration depth of liquid steel into the mould. He stresses the importance of correct ramming of a sand mixture of a correct grain shape. Ratingen sand additions to a sand mixture give the required properties.—T.G.

Method for the determination of the specific surface, grain size and grain structure of foundry sands F. Hofmann (*Giesserei*, 1960, **47,** Feb. 11, 49–56) A method is described for the determination of the shape of the sand grains of foundry sands and an expression is derived for classifying the grain shape. Another method has been developed for the determination of the porosity or internal structure of the sand grains, this coefficient expresses the water-holding qualities and requirements.—T.G.

Sands suitable for the CO_2 process and their effect on moulding O. Gerstmann (*Giessereitech.*, 1960, **6,** Jan., 22–25) The properties of silica sands—particularly grain-size and grain-size distribution—are discussed with special reference to their suitability for the CO_2 process.—T.G.

The effect of reagent additions on the properties of moulding sands A. J. Anderson (*Brit. Found.*, 1959, **52,** Dec., 560–565) The effect of additions of Na_2CO_3, pyrogallic acid, and sodium pyrophosphate on a sea sand containing bentonite and moisture were determined. The effect of the additions on the green strength and flowability was related to the viscosity of similarly treated clay suspensions but not to the pH developed.—A.D.H.

Method of calculation for the permeability of foundry sand with grain distribution K. Hashimoto (*Rep. Gov. Ind. Res. Inst. Nagoya*, 1959, **8,** Nov., 780–785) A formula is derived relating the permeability of sand with the grain-size distribution of the sand. The formula is applicable to the actual mould in which sand grains of various sizes are mixed as well as to a model consisting of layers of sand grains of uniform size.—T.G.

Properties of moulding materials at high temperatures. IX. The thickness of the hardened surface layer K. Futaki, M. Isotani, and Y. Nozaki (*Rep. Gov. Ind. Res. Inst., Nagoya*, 1959, **8,** Oct., 714–719) During pouring the moisture of the inside surface layer of a mould is evaporated and condenses at cooler parts in the interior of the mould. This difference in moisture content alters the properties of the mould and in turn that of the casting. For this the thickness of the dried-out hardened layer is the criterion. The thickness of this layer depends mainly on the grain size of the sand and on the drying conditions of the mould, but not on the quantity of any additions.—T.G.

Measurement of moisture in foundry sands R. G. Godding (*Bull. BCIRA*, 1959, **14,** Sept., 918–921) Methods are briefly outlined (17 refs).

Report on B.W.R.A. questionnaire on penetrameters F.E.18 Radiographic Panel (*Weld. J.*, 1958, **5,** Dec., 553–556) Two experimental types, one with 2-in. wires mounted in plastic and a step-type with holes in each step, were compared. Modifications to the former were suggested, the latter was considered more limited in applicability.

Preheating of pattern plates in order to reduce the adhesion of moulding sand K. Hoss and J. Horoszko (*Prz. Odlewn.*, 1960, **10,** (1), 1–8) The authors consider the possibilities of heating plates to reduce the adhesive forces between plate and moulding sand. This is to replace the method where parting substances are used. The variation of friction and adhesion forces with temperature is considered and methods of investigation outlined. It was found that heating to about 50°C reduces adhesion forces to zero and heating to about 60°C reduces friction forces to values no greater than those obtained by the use of parting substances. Several methods of heating plates are described.

Plastics as pattern materials L. Flood (*Gjuteriet*, 1960, (2), 19–26) Methods of producing plastic patterns are described, with a number of examples and photographs, and their properties are reviewed.

Practical calculation of the gating system for grey cast iron R. Nebel (*Giessereitechn.*, 1959, **5,** Dec., 341–353) A discussion of general principles is followed by some design details, and a system of nomograms and calculators is described for simplifying computation.

Gating for all types of castings O. Trenclé (*Giesserei*, 1960, **47,** Feb., 81–94) After reviewing the various methods for determining pouring time and for calculating gating systems, the author explains his method for evaluating pouring time and gating shapes and layout. He uses diagrams and nomograms for this purpose taking into account such variables as moulding method, casting method, casting metal, weight and shape of the casting (31 refs).—T.G.

Lightweight fireclay used for lining feeder heads N. F. Dubrov (*Stal'*, 1960, (1), 44) A note from the Ural's Sci. Res. Inst., for Ferrous Metals. Clay of dens. 1·5 used as lining reduced crop ends by 2–3%. If carefully made they last 18–20 melts. They also produce some reduction in rejects from other causes.

Shaw process licensees conference (*Machinery*, 1959, **95,** Dec. 30, 1378–1384) A summary of papers read at the conference in London.

Relation between the saturation indices and the volume of the pipe in grey iron I. Cazacu, T. Vadanici, and A. Fechete (*Met. Constr. Mas.*, 1959, (9), 763–768) A directly proportional relation exists between the volume of the pipe and the saturation indices of the iron. The reduction in the volume of the cavity can be brought about by a reduction in the saturation indices up to a limit which allows a pearlitic structure to form. To reduce saturation indices, the Si and P contents must be reduced; P in particular.

Possibilities of using a waterglass of 37 to 40° Bé as a moulding material binder O. Gerstmann (*Giessereitechn.*, 1959, **5,** Dec., 362–364) Properties of waterglass compounds with different moduli and densities are discussed, and it is shown that satisfactory core properties can be

obtained by hardening with a mixture of CO_2 and dry air.

Core binders F. Swenborg (*Gjuteriet*, 1960, **50**, (1), 5–8) The increased requirements for core binders to satisfy the demands of mechanical coremaking procedures and the need for improved dimensional accuracy are pointed out, and a description is given of methods used by a core binder manufacturer to test and develop his products.

CO_2 consumption in foundries O. Gertsmann (*Giessereitechn.*, 1960, **6**, Feb., 50–53) Studies on the consumption, and in fact on the waste, of CO_2 in foundries that work the CO_2 process showed that in the German Democratic Republic the consumption of CO_2 in relation to the consumption of water-glass if the latter is taken as 100% varied between 29 and 157%. It is stressed that certain control devices and other equipment are necessary for checking the quantity of CO_2 consumed. A number of case histories are quoted in which CO_2 was wasted on a real industrial scale. Proper injection techniques are described and illustrated.—T.G.

Solidification of grey cast iron H. Morrogh and W. Oldfield (*J. B'ham Met. Soc.*, 1959, **39**, Sept., 65–83; *Iron Steel*, 1959, **32**, Oct., 479–482) Solidification, graphite nucleation, and growth and effects of composition, pouring temp., and variations in nucleation.

Increasing the yield by applying slope casting in the steel foundry F. Dubiedzig (*Giessereitechn.*, 1960, **6**, Jan., 12–15) The merits of slope casting for steel casting are stressed. The mould is inclined at 10–30° to the horizontal, and the lower part of the mould should be reinforced to prevent breakthrough of the liquid metal. The number of vents and risers can be drastically reduced, this is a great advantage in fettling the casting. Using this method yield increases of up to 15% were reported.—T.G.

Minicast does it cheaper J. H. Cadieux (*Prod. Eng.*, 1960, **31**, Feb. 1, 44–45) Very small parts of C and stainless steels and other metals can be made by a method using plastic patterns. Tables of minimum wall thickness and surface finishes are given.

Commercial tolerances on permanent mould castings H. K. Barton (*Mech. World*, 1959, **139**, Oct., 430–434) A provisional system for assessing these castings at the design stage is explained.

Centrifugal castings (*Mach. Design*, 1959, **31**, Oct. 15, 156–160) Specifications for the castings and the properties of the alloys used and of the C and low-alloy steels are tabulated.

The action of external coolers during solidification of steel castings A. A. Skvortsov (*Izvest. VUZ Chernaya Met.*, 1959, (5), 29–33) Hydraulic integrators solve the problems connected with the action of the external coolers in the zone of the two-phase crystallizing layer and with the macrostructure, i.e. the size of the central porosity zone. Their use reduces the duration of the crystallization of the steel strip or cylinder up to a ratio of 0·4 and 0·6 between the thickness of the cooler and that of the metal.

The origin of the X-phase in cast iron moulds N. P. Nikolaichik and E. N. Nikolaichik (*Lit. Proizv.*, 1959, (7), 37–39) The network of cracks on the inside surfaces of the moulds is due to the oxidation of the cast iron during the filling with liquid metal. The internal oxidation depends on the graphite inclusions and on the size of the eutectic grain. During the oxidation of the cast iron, X′-phase forms in addition to the X-phase. The former has a compact structure and graphite veins. The presence of silicon and other elements forming complex compounds without a porous structure decreases the tendency to corrosion.

The problem of pinholes in steel castings R. Wlodawer (**Giesserei*, 1960, **47**, Jan. 14, 1–7) Studies on steel castings made from plain C steel produced in the basic converter showed that pinholes are, in most cases, caused by local oxidation of the steel in the mould. If slag is the cause the pinhole is surrounded by a slag envelope. H_2 may also cause pinholes but only in cases where the converter operation is at fault.—T.G.

Factors influencing the piping of grey cast iron H. A. Krall (*Giesserei*, 1959, **46**, Dec. 31, 1013–1015) The relevant factors in pipe formation are discussed with reference to the literature, in particular the statistical analysis reported by Gittus (*J. Res. Dev. BCIRA*, 1957, **6**, 456–483) (15 refs).

Foreign foundry troubles according to the technical literature of 1958 (*Fonderie*, 1959, Sept., 430–440) A survey covering cupola management, inoculation; problems affecting different types of castings, including iron and steel, copper, light alloys; enamelling; the ventilation of foundries and industrial dusts and their control is given, with references to Japanese and Russian works (207 refs).

Blowholes in castings, and methods of preventing their occurrence J. Ornst (*Slévárenství*, 1959, **7**, (11), 433–438) The physics and statistics of bubble formation in castings were studied, and formulae expressing the probability of the occurrence of bubbles in terms of the dimensions and physical properties of cores and moulds are derived. The equations were found to check well with data obtained in experimental work, and thus provide a means of control in the foundry, which should lead to a reduction in reject rates.—P.F.

The forced cooling of large iron castings singly or in small numbers A. A. Kornilov and V. D. Oreshkin (*Lit. Proizv.*, 1959, (5), 19–21) Large castings of 6 to 30 t take 2–10 days for cooling at the rate of 3 t per 24 h. At the Minsk Machine Tool factory a special cooling device has been introduced, consisting of a brick container with a massive cast iron bed plate perforated with special openings for air; the walls are fitted with many narrow tubes in the linings. Openings and tubes are connected to a fan. The use of these coolers has shortened the cooling time to 4 days, reduced internal stresses because of more even cooling and eliminated cracks.

Contribution to the illumination of foundries C. Saatmann (*Giesserei*, 1959, **46**, Dec. 17, 984–988) The importance of uniform lighting using modern light sources is emphasized, and the efficiencies of various sources are discussed and compared.

Effect of steel composition on hot tearing in castings N. A. Trubitsyn and P. N. Bidulya (**Lit. Proizv.*, 1958, (6), 22–26) Internal and external factors leading to the defect were examined with special reference to composition. Test heats of steels with 0·05–0·1%C, 0·1–0·2%Si, 0·2–0·3%Mn, 0·015%P, and 0·03%S deoxidized in the ladle with Al were poured and shrinkage was measured by means of a special device. Fluidity tests were also carried out. The temp. and compositions favouring hot tears were observed.

The decarburized layer in castings with fusible patterns O. V. Stupishina (*Lit. Proizv.*, 1959, (5), 36–38) Metallographic analysis has shown that the decarburized layer is the one in contact with the ceramic layer. On the surface of the section of the pouring gate in contact with the air no decarburization is seen; this is also absent on the surfaces in contact with the metallic sides of the mould. The conclusion points to the silica as the decarburizing agent, as it is the main constituent of the ceramic layer.

Defect 2230 F. Boussard (*Fond. Belge.*, 1959, **29**, July–Aug., 185–187) A flaw in a casting previously placed in category 2200 of the International classification of foundry defects is claimed to belong to category 2230. Reasons for this change are advanced together with a hypothesis on the cause of the flaw.—A.G.

Approximate general analytical solution of the problem of the solidification of casting of different shapes under the simplest conditions E. A. Iodko (*Lit. Proizv.*, 1959, (9), 41–42) An attempt at mathematically solving the problem valid for the following conditions: solidification takes place successively from the periphery towards the centre; at the initial moment the temp. of the liquid metal is constant at all points; the solidification takes place and is completed at one definite temp.; the solidification temp. does not change during crystallization; during solidification in the mould the conditions of heat loss do not change; and density, heat content, and heat conductivity of the molten metal are independent of temp.

On the smaller sand marks of cloudy appearance in roller bearing steel SUJ 3 Y. Matsumoto (*Tetsu to Hagane*, 1959, **45**, March, 341–344) The history of the defects is traced by various tests in the stages of steelmaking, ingot pouring, billet rolling, forging, and machining of the bearings.—K.E.J.

The effect of casting temperature on the formation of shrinkage cavities near hot spots in thin-walled steel castings M. Málek (*Slévárenství*, 1959, **7**, (12), 477–483) The effect of teeming temperature on the homogeneity of thin-walled castings is discussed on the basis of the author's detailed experimental work. The paper is an extract from a Ph.D. thesis.—P.F.

The use of AST T plastic mass in foundry practice E. I. Talankov (*Lit. Proizv.*, 1959, (9), 44–45) The AST–T plastic mass is used for repairing casting defects on non-working working surfaces and for patternmaking. The master pattern is made of wood. From it is made the mould from gypsum, alabaster, cement, or similar materials and then the pattern from AST–T plastic mass.

Repairing casting defects by self-hardening plastic masses V. D. Bezuglyi, A. A. Shturman, and L. N. Mats (*Lit. Proizv.*, 1959, (9), 43–44) Casting defects due to gas blisters and shrinkage cracks are repaired by the AST–T self-hardening plastic mass consisting of a powder and a fluid. The powder is polymethyl methacrylate emulsion containing benzoyl peroxide. The liquid methylmethacrylate contains a tertiary amine. The mass has the following characteristics. Heat resistance by Martens 90°; hardness 13–19 H_B; specific weight 1·18 g/cm³; impact strength 8–12 kg/cm²; UTS 450–500 kg/cm²; yield point in bending 800–1400; UTS in compression 1200–1600 kg/cm².

VACUUM METALLURGY

The effect of vacuum treatment on the quality of 30KhG SNA and ShKh15 steels T. M. Vorob'eva, I. P. Zabaluev, E. S. Kalinnikov, and A. F. Tregubenko (*Stal'*, 1959, (10), 904–907) Trials were carried out in apparatus previously described and the methods used, including Al treatment while under vacuum, are reported. Temperatures were measured and samples taken for analysis for H, O, and N. Pouring at 4–5 t/min, H_2 was reduced 16–24% mechanical properties improved but inclusions were unchanged. Shortening of the oxidation period gave some improvement in impact properties.

Comparison of vacuum and air-cast steel. I. Special features of vacuum ingot-casting process T. Suzuki and T. Asakuma (*Tetsu to Hagane*, 1959, **45**, Aug., 793–799) General features of the process are reviewed, e.g. drop size of the steel stream, range of pouring speed, segregation of inclusions, and removal of gases (13 refs).—K.E.J.

On the vacuum casting of steel. III. Fundamental problems in vacuum casting T. Asakuma (*Tetsu to Hagane*, 1959, **45**, March, 277–279) Data presented include comparisons of physical and mechanical properties of forgings in Cr steel from conventionally- and vacuum-cast ingots.—K.E.J.

The role of carbon as a deoxidizing agent in the production of vacuum-melted steel G. H. J. Bennett, H. T. Protheroe, and R. G. Ward (*JISI*, 1960, **195**, June, 174–180) [This issue].

Evaluation of properties obtained from an air-induction and vacuum arc melted high-temperature alloy J. Bulina and J. T. Brown (*Trans. Met. Soc. AIME*, 1959, **215**, Aug., 571–577) Laboratory and pilot scale melts tested at normal and high temp., indicate that the properties obtained from vacuum-arc melted materials are 13% superior.—A.G.

Contribution to the reduction behaviour of some oxides and oxide compounds in the fractionated vacuum-fusion process in the carbon crucible H. Schenck and K.-D. Unger (*Arch. Eisenh.*, 1959, **30**, Sept., 549–552) Calculations of decomposition pressures for oxides under vacuum-fusion conditions give results substantially above the furnace pressure, and discrepancies between calculated decomposition pressures and observed reduction temperatures must be due to the influence of physical condition. Reduction experiments on certain oxide inclusions show that higher temperatures are required for the breakdown of silica and

alumina in vacuum fusion than is generally assumed. Possible errors in fractionated vacuum fusion are discussed, and a two-stage extraction at 1160 and 2000°C is recommended for determining the proportion of the unstable ferrous and manganous oxides to the total oxygen content as a supplement to residue analysis.

REHEATING FURNACES AND SOAKING PITS

A comparison of regenerative and recuperative soaking pits S. H. Brooks (*Iron Coal Trades Rev.*, 1959, **179**, Oct. 2, 457–467) A contribution to a conference on steel tube recuperators held in Paris in April. Diagrams of the Appleby-Frodingham pits and extensive details of operation and performance with an account of special tests made in both types are given. Regenerative pits showed a small advantage on test but in practice they tend to fall short of test performance by larger margins than do the recuperative type. Other factors also appear to be in favour of the latter type.

Reheating without oxidising in billet and forging reheating furnaces U. I. Rosengart (*Metallurg.*, 1959, (11), 25) If fuel burns with an extreme shortage of air, then simultaneously with a decrease in the content of oxidizing gases, an increase in the volume of reducing gases occurs and the furnace atmosphere may approach a neutral non-oxidizing one. The tests showed that, to heat steel without scaling, the amount of air during the burning of the fuel must be half the theoretical amount. A second important question in relation to the non-oxidizing heating of metals is the utilization of the heat of the incompletely combusted fuel which consists of 55–65% of the calorific value of the fuel. Two basic types of furnace exist for the utilization of this heat. In the first type, the products of incomplete combustion are burnt up outside the furnace chamber before the regenerators or recuperator in which the heat is used to preheat the combustion air. However, this ensures utilization of only a small part of the heat from the combustion products. In the furnaces of the second type, the products of incomplete combustion are burnt up in that part of the furnace chamber separated from the combustion chamber by an intermediate roof or in special pipes filled with refractory material, in the furnace chamber. This device permits the direct utilization of heat from incompletely burnt fuel for heating the metal. When an intermediate 50 mm thick carborundum roof was installed, the coefficient of fuel utilization increased 1·5 times, and the specific consumption of heat during this period remained extremely high. A sharp increase in scaling of the metal set in at temperatures exceeding 950–1000°C. Thus, it may be assumed that the first stage of heating, in an atmosphere where the products of incomplete combustion are being burnt up, may be carried out at up to 900–950°C without any noticeable oxidation of the metal. These data were confirmed by special tests carried out in the furnace chamber. The application to two-stage non-oxidizing heating is possible in continuous as well as batch furnaces.

Present-day possibilities of low-scale and scale-free heating of steel for hot working P. O. Veh (**Industrie-Anzeiger*, 1959, **81**, April 7, 410–412) The use of combustion gases as protective atmospheres for furnaces and various types of furnaces and induction-heating equipment are reviewed and diagrams are given.

Furnaces for rapid throughput and walking beam furnaces for reheating all types of steels J. Dineur (*Centre Doc. Sidér. Circ.*, 1958, (6), 1295–1314) The author discusses and compares the construction, operation, and applications of the two types of furnaces.—R.P.

Radiation recuperators in soaking-pits R. Kremer (*Hutnik*, 1959, **9**, (12), 405–408) The mode of operation and economies of recuperators are discussed. It is suggested that metal radiation recuperators used in conjunction with convection recuperators may provide the most economical utilization of fuels.—P.F.

Automatic regulation of the thermal regime of soaking pits Z. Volf (*Hutnik*, 1959, **9**, (9), 300–303) The method developed and employed in the Klement Gottwald Steelworks in Czechoslovakia is described in detail.—P.F.

Design and operation of rolling mill furnaces during the last four decades K. O. Borchers (*Stahl Eisen*, 1959, **79**, Oct. 29, 1591–1601) An illustrated review of the developments in the design of rolling mill furnaces. The importance of economical operation is stressed (72 refs).

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

The construction of industrial furnaces (*Chal. et Ind.*, 1959, **40**, June, 550–620) Some examples with illustrations are given of metallurgical furnaces constructed by the Société Fofumi.

Flames and furnaces. Laws of heat transfer M. W. Thring (*Iron Steel*, 1959, **32**, Dec., 572–575) Laws of conduction and convection are stated and discussed, and nomograms are reproduced for calculating forced convection in the following three cases; between a tube bank and a gas flowing at right angles to the bank; with a gas flowing round a tube at right-angles; and with a gas flowing inside a tube.

High-temperature total radiation heating (*Chal. et Ind.*, 1959, **40**, June, 69D–76D) Characteristics of high-temperature total radiation burners are outlined with their application to industrial furnaces, several of which are illustrated and described.

Convection and radiation in high speed heating N. H. Davies and R. J. Reed (*Ind. Heat.*, 1959, **26**, Aug., 1546, 1550, 1552, 1554, 1556, 1558, 1626) By 'high speed heating', the authors imply (1) that a furnace temperature greater than the final metal temperature is employed; (2) arrangement of heat source and work to permit application of radiation and convection heating to a maximum number of sides of the heated piece. The factors affecting rate of heat transfer, and ways in which they can be utilized to increase the rate of heating are considered. The advantages and applications of high speed heating are discussed.

Straight line installation provides automatic atmosphere heat treating F. V. Horak (*Ind. Heat.*, 1959, **26**, Aug., 1528, 1530, 1532, 1534) One man, using a 'shuttle buggy', is able to heat-treat an average of 460 lb/h owing to the layout and mechanical handling methods used by the Harnischfeger Corp. The types of furnace used are described.

Effect of the composition on the heat-treatment and structure of high-manganese steel H. Takada (*Tetsu to Hagane*, 1959, **45**, March, 351–353) *S*-Curves are given for 0·93%C, 11·32%Mn, and 1·27%C, 11·17%Mn steels, and steels containing approx. 14·5%Mn are also discussed.—K.E.J.

Success in the speciality steel field is in direct proportion to heat treating versatility R. G. Piper (*Indust. Heat.*, 1959, **26**, Oct., 1941–1952) For production of a diversity of products, e.g. turbine casings, bearing rings, and special forgings and castings, extensive heat-treatment facilities are needed. Details are given of a plant containing beehive, box-type, and car-type furnaces, water and oil quenching tanks and a flame hardening machine.—K.E.J.

Cast rolls brave higher heats (*Iron Age*, 1959, **184**, Aug. 13, 96) Improved roll life in high temperature roller hearth furnaces is said to have been achieved through the use of centrifugally cast 22H alloy. This retains its strength up to 2250°F and resists oxidation.

Studies on subzero treatment of steels. II. Effect of subzero treatment on the mechanical properties of high speed steels H. Susukida (*Tetsu to Hagane*, 1959, **45**, March, 336–338) Data for SKH 2, 3, and 4 steels include the relationship between methods of heat treatment and the temper hardness, and specific wear factors for various heat treatments.

The surface hardening of cast irons W. Patterson and R. Döpp (*Giesserei*, 1960, **47**, March 10, 105–112) The main requirements for a routine application of surface hardening of cast irons is the knowledge of the following factors: Structure, hardening temp., section size, required heat input, holding time, anomalous temp., effect of double heating, etc. Microstructure has a marked effect on the rate at which any given austenitic C content is attained. This is important as the degree of surface hardness obtained depends solely on the magnitude of the carbon content in the γ-solid solution at the time of quenching.—T.G.

Controlled atmosphere hardening and cleaning of saw blades in new installation at Disston Division D. Singley (*Ind. Heat.*, 1959, **26**, Oct., 1977–1984) For production of hand- and power-tool equipment such as saws, blades, and frames, quality has been improved and productivity increased by replacing a system based on a chain conveyor furnace by a semi-automatic batch furnace, an 800 ft^3/h controlled-atmosphere generator, an automatic dewpoint signal controller and a vapour degreaser. A motorized transfer car feeds the degreaser.—K.E.J.

Induction hardening practice A. G. Gardner (*Mech. World*, 1959, **139**, Nov., 470–476) The theory of induction heating is developed and its application to hardening is explained with some discussion of applications.

Spaced inductive surface hardening K. Schönbacher (*Elektrowärme*, 1959, **17**, Aug., 289–295) Total and selective surface hardening techniques are discussed, particular reference being made to the selective hardening of gear teeth.

Induction heating and controlled cooling rapidly produces quality case on axle shafts F. W. D. Corp. (*Ind. Heat.*, 1959, **26**, Nov., 2246–2248) A 50-kW Allis-Chalmers induction heater with a Thyratron grid type power control is used; a controlled-temp. quench block can operate with oil or water.—K.E.J.

Progress in induction heating D. H. Lapray (*Met. Treating*, 1959, **10**, Nov.–Dec., 10–12, 14) The history, theory, and applications of induction heating in the laboratory and in industry are briefly described.—S.H.–S.

Induction hardening D. Flament (*Mét. Const. Méch.*, 1959, **91**, Dec., 913–916) In continuation of studies devoted to various hardening processes, heat transfer, relationship between electro-magnetic and thermal phenomena, and application of processes in practice are discussed.—S.H.–S.

Control of inductive processes R. Christ (*Elektrowärme*, 1959, **17**, July, 254–260) The automation of induction heating processes is reviewed, and several examples are given, including progressive feed rotary hardening, preheating billets, and the temperature control of induction strip tinning equipment. A new type of automatic kVA control on a large-capacity induction melting furnace is described.

Progress in the induction hardening of crankshafts G. Seulen (*AEG Prog.*, 1958, (4), 344–351) The focus inductor and loop inductor methods of induction hardening are described and apparatus is shown.

A survey of induction heating K. L. Moon (*BEAMA J.*, 1959, **66**, Nov., 138–143) General principles and uses are noted.

Induction hardener helps axlemaker eliminate warping, prune costs (*Steel*, 1959, **145**, Aug. 17, 100–101) In an automatic Westinghouse unit, axles are rotated horizontally while induction coils and quenching sprays move along the axles at 1/10 to 1/4 in/sec. Advantages claimed are increased strength and control of distortion.—A.G.

The constitution of spark-treated metals H. J. Goldschmidt (*Iron Steel*, 1959, **32**, Oct., 469–471) The mechanism of spark hardening is discussed, and the occurrence and importance of high internal stresses is shown.

A case for nitriding steel. I: II F. W. Schultz (*Eng. Found.*, 1959, **25**, Oct., 45–48; Nov., 37–40, discussion, 40–44) The process, steels suitable for treatment and the effects are briefly considered. The Fe–N diagram is shown and mechanism of hardening is discussed. Fatigue tests are quoted and various other factors are referred to.

Investigating the behaviour of the nitrided layer on components and fittings at high temperature A. V. Ratner and L. G. Leonova (*Teploenergetika*, 1960, (1), 59–63) Nitriding may be recommended for steels type 38Kh-MYuA for shafts for steam equipment with a temp. not above 520–530° because at higher temp. the surface hardness is reduced and also the resistance to erosion. Nitriding to strengthen shafts of austenitic steel type EI-405 may be recommended for a temp. of 600°C.

Effect of thermal treatment on the decarburization and fissuring of steels in a hydrogen atmosphere at 500–600° under a pressure of 800 kg/cm² Yu. I. Archakov, I. D. Grebeshkova, and V. P. Teodorovich (*Zhur. Prikl. Khim.*, 1960, (1), 89–94) It has been established that with an increasing tapping temp. for 40 Kh steel and for melt 7475 (0·18% C and 3·05% Cr) the Cr content of the carbide phase is reduced and the rate of decarburization falls. It has also been shown that the sizes of the microscopic cracks increase. It was found that during electrolytic dissolution of these steels a new phase forms, the origin of which needs further investigation.

G.W.B. pit furnace for heat-treating jet engine parts G.W.B. Furnaces Ltd (*Wild-Barfield Heat-Treat. J.*, 1959, **7,** Dec., 8–9) A 2 ft × 4 ft 3 in. dia. furnace rated at 120 kW (reducible for lower temp. ranges) is described.

Stress relieving a large reactor pressure vessel (*Mech. World*, 1959, **139,** Oct., 448, 449) The *in situ* treatment of the Berkeley reactor pressure vessel with a 2½ mW installation with radiant heaters is described.

Batch type furnace with side annealing chamber speeds controlled atmosphere heat treatments W. E. Bassett Co. (*Ind. Heat.*, 1959, **26,** Nov., 2265) The furnace, built by Surface Combustion Corp., uses a variety of atm. for bright hardening, annealing, carburizing, and carbonitriding. The attached chamber cools an 800 lb load from 1550° to 600°F in ~5 min.

Continuous annealer increases tin plate production at Kaiser plant Kaiser Steel Corp. (*Ind. Heat.*, 1960, **27,** Jan., 92–93) The new plant comprises a pickling line, continuous annealer, temper mill, and electrolytic tinning line.

Double heat treatment produces tough, wear-resistant, cast steel freight car wheel L. DeBoer (*Ind. Heat.*, 1959, **26,** Dec., 2483–2496) Details are given of two automatic conveyorized continuous furnaces built by Surface Combustion Corp., wheels in cast 1·5% C steel are made tough and wear resistant by double annealing (at 1750° and 1450°F) with a controlled cooling time between furnaces.—E.K.J.

New vertical closed quench furnace Electric Resistance Furnace Co. (*Brit. Eng. Transport*, 1959, **42,** Nov., 117–118) A pit-type gas carburizer with closed quenching arrangement is shown.

Studies of the quench-ageing of mild steels from various methods of production M. Nacken and W. Heller (*Arch. Eisenh.*, 1960, **31,** Jan., 39–46) Iron and mild steels produced by various methods were used in a study of the decrease of dissolved carbon with time during ageing. The damping capacity was used as a measurement of the amount of carbon dissolved. Decay time depends on purity and carbon content, but with increasing purity and increasing carbon content decay times are obtained that are too low. The activation energy of diffusion in α-iron was found to be 20 800 cal/g-atom which is independent from the degree of purity of the iron. The mechanism of nuclei formation was also studied.—T.G.

Cold treatment for better properties R. S. Jamison (*Met. Progr.*, 1959, **75,** March, 128–130) Chilling of heat-treated steel parts to −120°F transforms retained austenite to martensite. Commercial refrigerating units are doing this on a wide variety of parts. These units are briefly described and the field of application of this process outlined.—T.G.

Metal stability through cold treatment R. S. Jamison (*Met. Treating*, 1960, **11,** Jan.–Feb., 2–3, 51) Treatment of alloy steels at −120° to −150°F is described. Non-ferrous uses are noted.

The tempering characteristics of a commercial, high-silicon low-chromium carbon steel S. Niedzwiedz and A. Taub (*Met. Treating*, 1960, **11,** Jan.–Feb., 12–13, 46) A steel, Pompey PSK, similar to SAE 9260, 9261, and 9262 was austenitized and tempered over a range of conditions and the hardnesses determined.

Causes and prevention of surface fissures on hot-worked steel products. III. On the enrichment of tramp elements on the surface layers of steel by oxidation while heating T. Ohtake, K. Ishizaki, and N. Eguchi (*Nippon Kinzoku*, 1958, **22,** Dec., 640–644) Data are given for the enrichment of Cu, Sn, Ni, As, and S in the surface layers, and for the diffusion coeff. of Cu and Sn in steel. The concn. of these two elements is less in scale than in the matrix.

Protective gases G. Kluge (*Wire*, 1959, (44), Dec., 171–178) In connection with the bright annealing of wire, various types of protective gases, their properties, reactions and production are described, their costs compared, and process control and types of wire annealing furnaces are reviewed briefly.

The hardenability of spheroidal graphite cast iron J. Gittus (*Iron Steel*, 1959, **32,** Dec., 559–565) The variation of mechanical properties with change in section of quenched and tempered ductile iron wedges was taken as the most appropriate measure of hardenability. Of various combinations of Ni, Cr, Mo, and Mn contents the best composition for castings up to 4 in. thick is 2% Ni and 1¼% Mn on the basis of the wedge tests. Mo shows no special advantage, and Cr up to 0·4% is harmful (14 refs).

On the possibility of raising the temperature of case-hardening type 20 steel V. G. Podomitsyn (*Izvest. VUZ. Chernaya Met.*, 1959, (7), 87–89) An increase in the cementation temp. of type 20 steel greatly shortens the duration of this process and causes at the same time super-saturation of the steel surface with carbon, a coarsening of the structure of the cemented steel and a reduction in plasticity. The super-saturation is removed in the subsequent stages by a neutral atmosphere (in gaseous cementation) or by a short anneal a 1050° in a neutral salt bath.

On the heat-treatment of Hadfield steels P. Fremunt and A. Loreuc (*Slévárenství*, 1959, **7,** (8), 309–316) An investigation of the effect of variations of the C and Cr contents, as well as of annealing and tempering times and temperatures on the hardness of Hadfield steels showed that maximum hardness with all the steels was attained after about 48 h at 550°C. The Cr and C contents lie within the limits given by Czechoslovak Standard Specifications. Low carbon contents lead to low hardness. Cr does not affect the hardness but influences the amount of carbide precipitated during heat treatment. The transformation of austenite into pearlite and other phase-changes were studied micrographically.—F.F.

Thermal treatment of low alloy iron used for rolls L. F. Molotkov and E. M. Chernevich (*Izvest. VUZ. Chernaya Met.*, 1959, (7), 91–95) The depth of low alloy cast iron susceptible to hardening depends on the temp. of quenching and of superheating. The maximum hardness for an iron quenched from 800–900° is found at a depth of 3–4 mm from the surface and at 1000° at 12 mm; the fully quenched layer attains a thickness of 20 mm. A preliminary heating to 1000° increases the depth of low alloy cast iron susceptible to hardening to 42 mm.

Surface-hardening of all-black malleable W. Patterson, D. Ammann, and R. Dopp (*Giesserei wiss.-techn. Beih.*, 1960, Jan., 1491–1512) The authors studied various methods of flame-hardening of all-black malleable using a towns gas–oxygen mixture. The experiments are described in detail and the results presented in numerous graphs, diagrams, and micrographs. It was found that quenching from the required nominal temp. as soon as it has been reached is successful only in a very few cases, surface hardness is usually too low and the hardness of the core too high, but slow cooling in air after reaching the required temp. and heating up again with subsequent water quenching gave excellent results with respect to surface and core hardness. During the cooling period in air a marked increase in the pearlite content was noted (41 refs).—T.G.

Study on the continuous gas carburising furnace. IV. Effects of specimen size on the residual stress of a circular test piece A. Tsutsui and T. Furumoto (*Nippon Kinzoku*, 1959, **22,** Sept., 457–461) The max. stress value of solid and hollow cylinders decreased with decrease in length; that of disc-shaped and annular test pieces increased with increase of outer dia., and increased with dia. when the ratio of inner to outer dia. was constant. **V. Carburizing ability of steel** A. Tsutsui and M. Ichihara (462–465) Results quoted concern the variation of carburization with the furnace charge, the variability of carburization of Cr–Mo steel, problems caused by deoxidation, and the superior carburization of carbon steel compared with Cr–Mo and Ni–Cr steels.—K.E.J.

Automatic heat treatment hardens stainless knives Oneida Ltd (*Steel*, 1959, **149,** Sept. 7, 98) A brief description is given of an automatic heat treatment plant handling 1500 knife blades an hour. Special gas-fired radiant burners are used and flame impingement is avoided.—A.G.

New heating method licks sprocket hardening problem Chain Belt Co. (*Iron Age*, 1959, **184,** Sept. 10, 190–191) In the process described gears are rotated with their teeth immersed in a salt bath. After heating is complete the parts are rotated at 150 rpm in an oil quenching tank. A wide range of sprockets can be treated in this way with a minimum of distortion.

Hardness and the Sulfinuz method Y. de Villemeur (*Mét. Corr. Ind.*, 1958, **33,** July, Aug. 324–334) The effect of the method on plain and alloy steels is discussed. In many instances, hardness is found to be due to nitrides formed during treatment. Improved fatigue strength is obtained but the material is more brittle.

Nitriding locomotive cast iron crankshafts M. I. Rotenberg and A. V. Zapol'skaya (*Lit. Proizv.*, 1959, (10), 24–27) Experiments were carried out at the Kolomna locomotive factory on nitriding specimens in a laboratory furnace fitted for automatic temperature control and the necessary equipment. The maximum hardness of the order of 550 H_v is obtained by nitriding between 530–560° and the lowest hardness about 300 H_v between 650–670°.

Fundamental study on cyaniding and carbo-nitriding. III. On the outer-layer differential thermal dilatation method F. Yoshikawa (*Nippon Kinzoku*, 1959, **22,** Sept., 454–457) A theoretical model is set up for dealing with materials such as carbonitrided specimens where the coeff. of thermal expansion changes with depth, and is shown to be applicable to carburized and nitrided specimens.—K.E.J.

X-Ray method of controlling the depth of decarburization of high speed steel P. L. Beostotskaya, V. S. Dmitrieva, and M. F. Longinov (*Zavods. Lab.*, 1959, (5), 558–559) In *ibid.*, 1956, (12), M. D. Perkas described a method of determining the depth of the decarburized layer of carbon steels based on the fact that the extent of the formation of the tetragonal martensite lattice after quenching increases with an increase in the carbon content. This method has now been adapted to control the decarburization of high-speed steel. In addition, the X-ray determination of the depth of decarburization, by measuring the intensity of the (111) line of the residual austenite may also be used as a method of control.

Large capacity controlled-atmosphere furnaces of pit type used to heat-treat high-temperature alloy parts E. J. Costantino and J. J. Prandi (*Indust. Heat.*, 1959, **26,** Oct., 2185–2191) Facilities used by E. and J. Heat Treating Inc. for a range of parts to close tolerances in SAE 4130, SAE 4340, 17-7 PH, 17-4 PH, AM 350, AM 355, and austenitic stainless steels include a large subzero tank, liquid honing arrangements, pit-type electric furnaces with suspension jigs, and horizontal box-type furnaces.—K.E.J.

Versatile car-bottom furnace used for completely automatic heat treating over broad temperature range (*Ind. Heat.*, 1959, **26,** July, 1391–1394) The gas-fired furnace can be used for general annealing, normalizing, stress-relieving, etc. Complete heating, holding, and cooling cycles (e.g. normalizing and annealing) can be accomplished in fully automatic conditions.—K.E.J.

Experiences with heating and annealing in a modern German strip mill W. Trinks (*Ind. Heat.*, 1959, **26,** Sept., 1753–1758) It is found that most of the heat is imparted to the coiled strip axially from the ends. The result is that the wider the strip the less the length that can be annealed within a given time. For example if the strip is 59 in. wide only 1·4 net t can be annealed per h under one hood whereas if the strip is only 23·6 in. wide, 2·7 net t can be annealed.

Heating and cooling in continuous furnace closely controls annealed structure for machining A. G. Sturrock (*Ind. Heat.*, 1959, **26**, Sept., 1704–1706, 1708, 1710, 1712, 1848) Practice at the Wyckoff Steel Company in Chicago is described. The quality requirements are outlined. These are attained by use of an accurately controlled furnace atmosphere, by continuous operation, multiple heating-cooling chambers, eductors to provide uniform heating and automatically controlled atmosphere generators.

Heat treating the stainless steels. III S. W. Cole (*Ind. Heat.*, 1959, **26**, Aug., 1524–1526) The annealing procedure is given for the ferritic Cr stainless steels in the ASM series, and the ranges of hardness and typical mechanical properties resulting from this treatment are tabulated for sheet, strip, bars, and wire.

On the size change of globular cementite and hardness in various spheroidizing processes of ball-bearing steel K. Tasaka (*Tetsu to Hagane*, 1959, **45**, March, 347–349).—K.E.J.

Study on high speed tools. X. XI. Isothermal transformation annealing of high speed steel (SKH 2 and SKH 9) H. Hotta (*Tetsu to Hagane*, 1959, **45**, March, 334–335) Data for SKH 2 and SKH 9 steels include quenching, isothermal transformation annealing, and stepped annealing curves.—K.E.J.

Annealing methods integrated for processing stainless steel strip at new Jones and Laughlin Plant (*Ind. Heat.*, 1959, **26**, Sept., 1694–1696, 1698, 1700) A description of plant and equipment including a 52 in. Sendimir cold rolling mill and two continuous annealing and hot pickling lines.

Jet cooling speeds continuous annealing Wheeling Steel Corp. (*Steel*, 1959, **145**, Sept. 21, 92) The installation described cools tin plate strip from 900 to 250°F by means of eight passes through a tower-type unit equipped with jet cooling. The cooling gas used is 8%H_2 and 92%N_2. Advantages of the process are listed.—A.G.

Quenching of steels. The how and why of quenching C. A. Siebert (*ASM Publication, from papers presented at National Metal Congress, Oct.* 1958, *at Cleveland, Ohio*, 1959, 1–9) A review of the assumptions customary in hardenability calculations and an account of the approach from the heat flow concept are given. **Quenching—a thermal process** (11–27) Heat transfer concepts are applied in more detail and the nature and role of boundary conductance are developed. Examples of various shapes are worked out, quenching media are discussed, and the concept of cooling rate is examined. Measurement of boundary conductance is described. **Evaluation of quenching media** G. H. Robinson and H. J., Gilliland (29–43) Hardening power and cooling power were assessed in several ways. The magnetic test correlated best with hardening power as measured by hardness actually developed in rounds of 1046 steel. The effectiveness of oils varies with the type of steel. Surface condition influences quenching rate, an oxidized surface quenching more rapidly. Agitation has more effect with low-cooling power oils than with 'premium' oil, but mild agitation has a relatively great effect compared with still oil. Oil at 135°F cools rather better than oil at 78°F. **Hot oil quenching** W. C. Hiatt (45–49) An account of marquenching practice at the International Harvester Co. Various factors are briefly discussed including distortion and oil regeneration. **Basis of selection of quench media** R. H. Lauderdale (61–66) Choice is based on the hardenability of the steel, section size, and symmetry, dimensional tolerance, physical properties required, and availability of media and equipment. These are discussed and their effects are illustrated. 'Plastic' media and the radial spray methods are included. **Automatic quenching of steels** O. E. Cullen (67–77) Automation is discussed and typical installations are shown diagrammatically and commented upon.

Sorbitisation of crane wheels at the Nizhne Tagil' Combine N. A. Shchetkina, V. I. Purgina, and A. E. Dorfman (*Stal'*, 1959, (12), 1124–1125) A machine with quench tank for sorbitizing the rims of crane wheels (for overhead travelling cranes) is described. The wheels were gas-heated to 840–860°C for 1½–2 h and rotated partially immersed in running water. The tests made and the conditions finally arrived at are outlined. No sign of wear has appeared after six months.

On the deterioration of quenching oils. V. On the deterioration of quenching oils by thermal decomposition M. Tanaka (*Tetsu to Hagane*, 1959, **45**, March, 329–330).—K.E.J.

Studies on quenching media. XIV. The influence of water contamination on the cooling ability of oils M. Tagaya and I. Tamura (*Nippon Kinzoku*, 1958, **22**, Dec., 629–631) Differences are shown between the effect of water on a fatty (rape) and mineral (110-dynamo) oil; these depend on the amount of emulsion, since the effect is greatest in the emulsion-forming range. Water has little effect on hardening, but is extremely effective in influencing quenching distortion or cracking. **XV. The effect of flow rate on the cooling ability of liquids** (631–636) Studies on water and three oils, in the turbulent state, show that cooling ability increases with Reynolds No., but reaches an upper limit with highly viscous oils. Some desirable features in the design of quenching tanks are suggested (16 refs).

Production of metal for cold upsetting N. A. Smol'yaninov and I. G. Shushakov (*Stal'*, 1959, (12), 1136–1140) Methods of heat-treating the drawn wire rod were compared. With the treatment indicated, cold killed steel with normal Si content can be upset with a deformation up to 90% or more. By quenching and tempering killed steel can be obtained with uniform structure and high ductility.

The effect of intermediate tempering on the wear resistance of metal D. I. Taracko (*Izvest. VUZ. Chernaya Met.*, 1959, (5), 91–95) Three phases may be distinguished in the formation of the focus of fatigue failure. The first is related to the strengthening of the weakest grains or blocks, the second, in which softening occurs at the same time as strengthening, is related to the accumulation of vacancies and their arrangement into columns with an increase in local stresses to the level of the cohesion forces. The third phase is characterized by irreversible processes, i.e. the combining of the accumulated vacancies and the formation of fatigue microcracks which then pass into the macro-cracks characteristic of fatigue.

Study on heat-treatments of bearing steel. II. Effect of carbide particle size, subzero and martemper-treatments upon hardness and compressive breaking strength of bearing steel Y. Iwama (*Tetsu to Hagane*, 1959, **45**, March, 339–341).—K.E.J.

Study on graphitic steel. VI. Heat-treatment of graphitic steel of the Fe–C–Si system. II T. Sato and S. Toya (*Nippon Kinzoku*, 1959, **22**, Sept., 446–449) Work with several Fe–C–Si steels shows that increase in C and Si contents has little effect on the decomposition temp. of retained austenite, increases the starting temp. of the third stage of tempering, increases the graphitization ratio of tempered steel, and reduces the starting temp. of graphitization during tempering.—K.E.J.

FORGING, STAMPING, DRAWING AND PRESSING

Plasticity and resistance to deformation during forging A. Vach (*Hutn. Listy*, 1959, **14**, (8), 66–70) The calculation and measurement of rolling and forging pressures, particularly appertaining to the hot working of steels, are discussed with reference to various formulae which have been proposed in the last few years.—P.F.

New heavy forge A. A. Bocherov and D. D. Kargin (*Vestnik Mashin*, 1959, (5), 45) A description and photograph of a new forge with weight of hammer 26 t and of anvil block 12 t are given.

Heavy forgings in Poland L. Kelm (*Hutnik*, 1959, **26**, (9), 366–368) The author reviews the steel industry in Poland and points out that forging production is mainly concerned in supporting the manufacture of presses in the 1000–3000 metric t range.

Mode of operation and design of power forging hammers F. Keilholz (*Stahl Eisen*, 1959, **79**, Oct. 26, 1615–1624) The author compares power presses and power hammers with respect to contact time of tool and work-piece. The design of a number of types of power hammers is described and illustrated. Finally, the author deals with the advantages and disadvantages imposed by the employment of compressed air and steam for driving such hammers.—T.G.

Modern forging-hammer foundations G. Rau (*Stahl Eisen*, 1960, **80**, Feb. 4, 170–172) An illustrated review of the various types of foundations for forging hammers which aim at eliminating, or at least reducing, vibrations.

Compressed-air driven forging hammers K. Zimmer (*Stahl Eisen*, 1959, **79**, Oct. 26, 1625–1627) Some design details—mainly the control—of a pneumatic forging hammer with a ram weight of 2 t are given. The suspension of the hammer is briefly dealt with.—T.G.

The use of Mn–V steels for large forgings R. Sèjnoha (*Hutn. Listy*, 1959, **14**, (8), 743–748) The formation of fine fissures in the head portion of large forgings made of steel containing 0·23%C, 1·10%Mn, and 0·20%V is ascribed mainly to the presence of V. In forgings which, because of their size, do not permit a thorough forging-through, it is recommended either to discontinue the use of V additions, or to reduce the V content to a minimum. Possibly replacement by another element may prove best.—P.F.

The use of hard alloy inserts in upsetting dies V. I. Dudorin (*Vestnik Mashin*, 1959, (4), 62–64) Various matrices are described and the different types of steel for inserts are tabulated.

The effect of overheating on forged and stamped parts for use in aviation A. Rodriguez de la Pena (*Tecn. Met.*, 1959, **15**, July–Aug., 169–185) [In Spanish] The author defines overheating and burning and discusses the essential differences between them and the various methods that are available for the detection of overheating. A study of the effects of overheating on the mechanical properties of a steel (0·34%C, 0·60%Mn, 0·28%Si, 0·017%P, 0·016%S, 0·87%Cr, 3·32%Ni, and 0·53%Mo) is reported and property charts for the quenched and tempered conditions as a function of the degree of overheat are given. These show the marked effect on ductility and that incipient overheating occurs at 1275°C.—P.S.

On the hot-cold working of medium carbon steel M. Ono (*Tetsu to Hagane*, 1959, **45**, March, 285–287) Data are given for the relationships between reduction at 400°, 500°, and 600°C and tempering temp., and mechanical properties.—K.E.J.

Large diameter tubes. Use of hydraulic presses for forming and rectifying O. Tedder (*Iron Steel*, 1959, **32**, Dec., 578–579) Work at Chelyabinsk is reviewed.

Automation in the press shop (*Sheet Met. Ind.*, 1959, **36**, July, 526–534, 536) The uses of belt conveyors and the economics of labour versus lost production in a press shop of inadequate capacity were discussed, and various questions on automation were answered at a discussion forum of the Midland Branch of The Institute of Sheet Metal Engineers.

Redesign of product triggers many benefits Westinghouse Electric Corp. (*Steel*, 1959, **145**, Oct. 5, 94–95) Modifications in the design of the coils and cores of a distribution transformer have made automatic production possible. The transformer tanks are also made by an automated line and are tested by means of a fluorescent spray.—A.G.

Hydraulic presses for the fabrication of electrically welded pressure tubes N. Jackle (*VDIZ*, 1959, **101**, Dec. 11, 1706) A short description of a process developed in Russia for forming straightening and expanding electrically welded pressure tubes, using three hydraulic presses.

The rolling of rings and tyres and the layout of ring and tyre rolling mills K. H. Weber (*Stahl Eisen*, 1959, **79**, Dec. 24, 1912–1923) The operations and principles involved in the production of rings, for instance for ball bearings, and of tyres are reviewed and the machines for producing them described in detail. In the discussion, the deformation modes as suggested by the author were disputed.—T.G.

On the rigidity of stamping presses E. N. Lanskoi (*Vestnik Mashin*, 1959, (5), 50–53) It has been shown by various machine construc-

tion research institutes that the deformations of the press systems are proportional to active forces in excess of about 25% of those normally provided for. Calculations are given for various parameters of press and components.

Defining the forms of deformation and calculating the force in stamping M. V. Storozhev, E. I. Semenov, and S. B. Kirsanova (*Vestnik Mashin*, 1959, (4), 55–61) The process is divided into two stages and three zones and calculations are given for each.

Report on explosive forming. 3: Tube forming with and without dies J. Savitt (*Metalw. Prodn.*, 1959, **103**, Oct. 30, 1736–1738) Illustrated.

On noise control in the I.B.M. punching room T. Nakano, Y. Nambu, and Y. Iwanari (*J. Lab. Hyg. Iron Steel Ind.*, 1959, **8**, May, 18–21) Absorption plates of Vinyphon and Alflex (vinyl chloride) fitted on walls and ceilings reduced the noise level from 86 to 75 phons, particularly in the harmful high frequencies (25 refs).—K.E.J.

Cold working IV. Drawing Y. Kasuga (*Tetsu to Hagane*, 1959, **45**, Aug., 826–834) A review, mainly theoretical (68 refs).—K.E.J.

Definitions and mathematical relations of tube drawing processes A. F. Mohrnheim (*Wire*, 1959, (44), Dec., 161–165) Simplified formulas are stated or derived and methods of calculating various parameters, such as tube length, diameter, wall thickness, number of passes, etc. are illustrated by a number of examples.

Influence of the small arsenic content on the mechanical properties of sheets for deep drawing A. Kohn and J. Stremsdoerfer (*Rev. Mét.*, 1959, **56**, July, 101–102) A normal mild steel and one containing 0·06%As were rolled into 0·8 mm sheets and normalized. Both had considerable major and minor heterogeneity but only under severe deep-drawing conditions did the As-containing steel reveal a slight inferiority.—A.G.

A new method of testing deep drawing capacity and its application W. Engehardt (*Mitteilungen der Forschungsgesellschaft Blechverarbeitung e. V.*, 1959, Nov. 1, 287–292) The underlying principles of deep-drawing tests are outlined, the main methods of carrying out the tests are discussed and compared, and the design, operation, and results obtained with a new testing instrument developed by VEB Werkstoffprufmachinen of Leipzig are reported.

Ageing of soap baths for lubricating phosphated pipes A. Z. Grebenshchikova and A. Kukarskikh (*Stal'*, 1959, (10), 932) It was found that after 5–10 days the bath ceased to lubricate and the process was found not to be mechanical but to be due to zinc soap formation and this was prevented by rise of acidity by acid carried over by the pipes. Neutralization to pH 8 raised bath life to 4–5 months.

Conditions for the appearance of pickling embrittlement in tube drawing K. Takase (*Tetsu to Hagane*, 1959, **45**, March, 320–322).

Electronics in making wire and wire products (*Wire Ind.*, 1959, **26**, Sept., 885, 901) Electronic applications discussed included continuous diameter measurement, control of the assembly of wire products and the batching of fine wire items.—A.G.

Design requirements of high speed take-up operation P. C. Greene (*Wire Wire Prod.*, 1959, **34**, Feb., 195–196, 246) Problems involved in the automatic continuous reeling of wire on dual take ups are considered.—A.G.

The high speed dual take-up I. Minardi (*Wire Wire Prod.*, 1959, **34**, Feb., 201, 240–243) The major requirements of high speed dual take ups are discussed, namely: speed, control, automatic operation, serviceability, and safety.—A.G.

Some aspects of dual take-up economics and design B. K. Bigland (*Wire Wire Prod.*, 1959, **34**, Feb., 197–200, 242–243) Economic grounds are given for producing two types of dual take-up: a simple reliable machine and a fully automatic unit. Design problems encountered with both types are discussed.—A.G.

Radioisotopes and strain gauges in wire-drawing research J. Kieszniewski, L. Kus, J. Siewierski, and R. Wusatowski (*Prace Inst. Hutn.*, 1959, **11**, (4), 215–227) The rate of drawing of wire is limited since too high a speed reduces quality. To obtain the optimum rate, lubricants and lubricant pads were selected and their effect on die wear, the properties of the wire, and the consumption of energy were observed. The authors used a method where die wear was measured by the degree of radioactivity picked up by the wire as it was drawn through the die after the die had been treated with a radioactive substance. This research led to an increase of speed of drawing by 2·5 m/sec without affecting the quality.

The extrusion of steel E. K. L. Haffner and J. Sejournet (*JISI*, 1960, **195**, June, 145–162) [This issue].

Hydraulic horizontal extrusion presses W. Dohrn and H. Schmoll (*Z. Metallkunde*, 1960, **51**, Jan., 29–35) Some designs of press are described and illustrated, the advantages of two or four-column design pointed out, and drives and control systems discussed.

A method of calculating die holders for extruding flat ingots P. I. Perlin (*Vestnik Mashin*, 1959, (5), 57–58) Flat ingots are pressed through a die to make ribbed panels in one piece. A method for calculating the parameters of the die casing has been evolved at the Central Research Institute of Machine Construction. The casing is round and limiting measurements are given of the slits and tolerances for a few casings. The margin of error is approximately 2%.

Roll-extrusion, a new metal-forming technique A. W. Ernestus (*Metalw. Prodn.*, 1959, **103**, Nov. 13, 1841–1843) A brief account of the process with diagrams. The examples are non-ferrous.

ROLLING MILL PRACTICE

Historical development and present state of the theory of piercing in the manufacture of rolled seamless tubes B. Počta (*Hutn. Listy*, 1959, **14**, (10), 844–848) The development of tube piercing, and the theory of the process are surveyed. A rational basis for the design of roll-piercing equipment is outlined.—P.F.

Study of wall deformation during the hot reducing of tubes V. L. Kolmogorov and A. Z. Gleiberg (**Stal'*, *Rolling and Tube Supp.*, 1959, 171–179) Existing empirical formulae often give incorrect values. An expression is here derived for effects of rolling temperature, ovality of roll passes, and the properties of the steel on wall deformation and based on plasticity theory, and tests on a laboratory 150 mm mill were made. Carbon steel and stainless steel were used. A graphical method of solution was applied and good agreement with measured values is shown.

Recent investigations on the application of elastic anisotropy F. Straumann, O. Pohler, and H. Aerni (*Schweiz. Arch. Wiss. Techn.*, 1959, **25**, Aug., 279–285) The relationship of the formation of rolled texture to the roll dia., width of the stock, number of passes, and other factors is shown by means of several examples, and the connexion between texture variations and changes in the direction of the optimum plastic properties of rolled strip is pointed out. It is shown how the most favourable elastic properties can be obtained by suitable selection of drawing and rolling conditions. This is illustrated by photomicrographs and pole figures of patented steel wire rolled into narrow spring strip.

Rolling practice in the iron and steel plants of the U.S.A. V. P. Kozhevnikov (*Stal'*, 1959, (12), 1111–1113) A report of a visit of a party of Soviet metallurgists.

Special features of the plastic deformation in transversal upsetting and transversal and helical rolling S. I. Orlov and V. V. Shveikin (*Izvest. VUZ. Chernaya Met.*, 1959, (5), 55–68) A drawing out of the axial metal layers occurs in repeated transversal upsetting and helical rolling because of the large tensile stresses perpendicular to the external compression forces. The effect is like a collar forming on a specimen when pulled. The experiments here described show that the deformation in repeated upsettings is similar to that in helical rolling only for forgings with a progressive turning of the specimen through a small angle.

A contribution to the study of the deformation of bimetallic rod in hot rolling R. Fishgold and I. Dragan (*Studii Si Cercet. Met.*, 1959, (3), 377–390) The essential parameter which conditions the distribution of the deformation of a bimetallic rod (for given conditions of plastic treatment) is the ratio between the two thicknesses $H_1/H_2=K$ where H_1 and H_2 are the thicknesses of the two layers, (steel and non-ferrous metal) before rolling. During rolling, the thicker layer takes up the greater part of deformation in thickness. Good cladding depends on the selection of the optimum deformation coefficients and especially on the determination of the optimum value for $H_1/H_2/h_1/h_2$ where h_1 and h_2 are the thicknesses of the two layers after rolling.

Resistance to deformation of carbon steels during high speed hot rolling Ya. V. Shamets and M. A. Zaikov (*Izvest. VUZ. Chernaya Met.*, 1959, (5), 45–53) The specimens of rectangular cross-section with a ratio h/D= 0·06–0·5 all of the same width of 15 mm were made of MSt2, 30, 50 USA and U10A steels, rolling temp. 800–1200°. From the tabulated results it may be seen, for example, that for an average thickness ratio of the specimens h/D=0·125 and a high temp. (1100°), resistance to deformation increases with an increase in the reduction ratio and then a reduction in the resistance is observed for large ratios of deformation (30–40%). At 900° this effect is not observed. Results in hot rolling at 1100° with different rolling speeds and reduction ratios are tabulated for these steels.

The deformation process in cross rolling V. S. Smirnov (**Stal'*, 1947, June, 511–518) The causes of cavitation in the core of a billet due to oblique rolling are considered in the light of experimental data. It is concluded that rupture is due to normal and not to shear stresses (11 refs).

Special features of the deformation of the metal in the rolling of sheets on the three-high stand type Lauta mill N. A. Chelyshev (*Chern. Metallurg.*, 1959, (2), 73–82) Experiments were carried out on the 850/560/850 three-high lauta type mill at the Kuznetsk Metallurgical Combine. The passage of the metal through the rolls was recorded by means of iron isotope ^{59}Fe which made it possible to follow the longitudinal and transversal deformation. Mathematical analysis shows that rolling is determined not only by the ratios of the diameters but also by the thickness of the rolled material for the given deformation and by the friction between rolls. These factors condition also the bending of the strip, the distribution of the torsional moments between the rolls, and also the horizontal forces in the stand.

The determination of the rolling forces during cold rolling M. Wenzel (*Stahl Eisen*, 1959, **79**, Dec. 10, 1872–1875) Mathematical. The author compares, on the basis of examples, formulae derived by various workers and comments upon their limitations and accuracy.—T.G.

The measurement of roll pressures on an intermediate stage grooved-rolls mill J. Sjlenár (*Hutnik*, 1959, **9**, (9), 306–310) Small hydraulic devices were used to check the roll pressure on hot rolling rectangular and circular bars of 4–5 in. final length of side or dia. respectively. The results were found to be about 20% higher than pressures calculated from formulae of Ekelund or Celikov.—P.F.

Measurement of rolling load in the five tandem cold strip mills K. Nakajima (*Tetsu to Hagane*, 1959, **45**, March, 283–285).—K.E.J.

Development work in rolling deformed concrete reinforcement bar, No.6 V. K. Likhov (*Stal'*, 1959, (10), 920–923) Rolling in the 260 mm rod mill using cast iron rolls from billets 130×130 mm cut into 165 kg lengths down to the necessary section in 24 passes is described. The rod has a spiral thread which is cut on a special lathe. Tolerances obtained are given.

Investigating the building up of steel rolls V. G. Malinovskii and A. S. Babii (*Stal'*, 1959, (10), 937) Electrical building up with powder electrodes under a ceramic flux was used.

Concerning the theory of planetary rolling A. N. Skorokhodov (*Chern. Metallurg.*, 1959, (2), 61–71) A commentary on the articles which appeared in *Iron and Steel*, J. H. Mort, (10–11), 1954; H. M. Walter (2–3), 1955, and D. M. Potter, (3), (11), (13), 1957.

Standardizing rolling on the medium three-high sheet mill by the pressure on the rolls measured by dynamometer V. G. Malinovskii and A. S. Babii (*Stal'*, 1959, (10), 937) A note from Enakievsk. The operation has been shortened by 2-3 passes increasing output 8-3%.

Increasing the strength of the working rolls on the three-stand cold rolling continuous mill V. F. Agapov (*Stal'*, 1959, (10), 936) A note from Magnitogorsk. Through-hardened rolls were superior to surface-hardened.

The modified Sims method of calculation for hot rolling K. H. Weber (*Neue Hütte*, 1959, **4,** Dec., 738–740) A discussion of the modification of the Sims equations for the calculation of rolling power and torque due to Cook and McCrum (*Calculation of load and torque in flat rolling*, *BISRA*, March 1958).

Contact compression and mean specific pressure during shrinking and rolling I. Ya. Tarnovskii and A. A. Pozdeev (*Chern. Metallurg.*, 1959, (2), 51–60) A mathematical study of the problem showing that by using certain integral equations of work it is possible to obtain with sufficient accuracy, functions for the distribution of pressures $p=f_1(x)$ from any law of distribution of contact tangential stresses $\tau=f_2(x)$.

The prospects of rolling with large deformations Z. Wusatowski (*Hutnik*, 1960, **27,** (1), 22–25) The article consists mainly of descriptions of several systems of hot rolling, with large deformations on an industrial scale. It was found that the most economical deformation was 90%. Rolling speeds and cross-section reduction data are also given. Apart from this, data concerning the economic aspects in a modern mill comes from the article 'Planetary Hot Mill' by D. M. Potter (*Iron and Steel*).

Mathematical aids to determine spread and reduction rates in rolling L. Moses (*Iron Steel Eng.*, 1959, **36,** Dec., 65–77) The use of the spread formula derived by Ekelund (*Steel*, 1933, Aug., Sept., Oct.) in solving spread and reduction rate problems is described, with examples of its application by Bethlehem Steel Co.

Mercury arc converters for rolling mill duties K. D. Phillips (*English Electric J.*, 1959, **16,** Dec., 27–40) The advantages offered by the mercury arc converters to all types of mill drives are described in a number of examples.

Why is mill roll manufacture still a 'custom' business E. P. Sandbach (*Iron Age*, 1959, **184,** Oct. 1, 80–82) Considerations involved in roll selection and types of failure are discussed with reference to rolls with flat bodies. The problems of 'firecracking' and 'banding' are dealt with together with means of overcoming them.—A.G.

The blooming mill and the continuous billet mill at the Bhilai Steel Works (*Iron Steel Rev.*, 1959, **3,** Dec., 43–44) The blooming mill consists of a two-high single-stand reversing mill designed to roll ingots up to 10-t weight, the continuous billet mill has 10 stands, half horizontal rolls and the other half vertical rolls. The output of the continuous mill will be 150000/year.—T.G.

Finishing grooves for rolling round steel bars F. Nitulescu (*Met. Constr. Mes.*, 1959, (9), 748–755) Detailed technical considerations for the construction of finishing grooves for round bars, calculating for the contraction of the steel on cooling, the tolerances given in the standards, etc.

'Cold' finishing school for steel: Bars leave Seattle Mill polished, well rounded H. E. Jackson (*Western Metalw.*, 1959, **17,** Nov., 46–47) The various types of finishing machines for steel bars are Sierra Drawn Steel Corp., Seattle, Washington, plant are described and illustrated.—T.G.

The production of rails with a higher tensile strength and durability K. Radzwicki (*Hutnik*, 1959, **26,** (12), 496–499) Since improvements known and applied in the USSR and USA cannot for the time being be applied in Poland the author suggests the introduction, on an experimental basis, of the de-gassing of the liquid steel in a vacuum chamber. Tests described in the article carried out on Bessemer steel gave satisfactory results.

Steel for Alaska 'Pioneers' roll first rebars in Seattle: mill destined for Fairbanks H. E. Jackson and N. Wood (*Western Metalw.*, 1959, **17,** Sept., 35–37) The work of a new steel mill in Seattle, destined to operate shortly on abundant scrap iron in Alaska is described.—S.H.–S.

Electrical controls in the steel industry. I J. C. Christie and J. T. Jones (*English Elect. J.*, 1959, **16,** Sept., 32–51; Dec., 3–15) A review of applications, especially to hot reversing and continuous mills, rod and bar mills and auxiliaries. The control schemes for a single-stand cold reversing mill and a five-stand tandem mill are among the typical control schemes discussed, and are taken as an example for the continual improvements made by the electrical industry for the steel industry. Two of these are: the replacement of moving elements by static devices, and the use of automatically programmed instructions to replace manually initiated commands.—T.G.

Electrical controls in the steel industry J. C. Christie and J. T. Jones (*Elect. Rev.*, 1959, **165,** Nov. 20, 681–685; Dec. 11, 823–828) Rolling and finishing mill controls, especially Ward–Leonard drive and control of auxiliaries and screw-downs, are described in the first part and problems of continuous cold-rolling in the second.

The quality problem in the production of rolled steel for screws and rivets for cold upsetting J. Haas (*Hutnik*, 1959, **26,** (11), 444–449) The chemical composition and mechanical properties of steels suitable for the production of screws and rivets is discussed. Killed and unkilled steels are considered. The composition of a new steel killed with Al is given (0·32–0·40%C, max. 0·40%Mn, max. 0·10%Si). In conclusion the working of the steel in the rolling mill is discussed.

A combined wire, light-section, strip and tube rolling mill G. Leder (*Stahl Eisen*, 1960, **80,** March 3, 297–299) A short description is given of the layout and equipment of the new rolling mill at BREDA Siderurgica, near Milano, Italy. The mill has a total of 23 stands, a pass sequence including data on the individual stands and their drives is presented.

Electrical equipment for two-stand temper mill (*Elect. Eng.*, 1959, **36,** May 11, 42–44) Control devices for motor drive check on strip tension, coil diameter, and compensation for mill acceleration are briefly considered.

Electrical equipment for an 18-in. strip and skelp mill drive P. E. Peck and W. J. Young (*BTH Activities*, 1959, **30,** Sept.–Oct., 193–204) An illustrated description of the equipment of the mill at Newcastle NSW.

Strip tension control reduces breakage US Steel Corp. (*Steel*, 1959, **149,** Sept. 7, 96) In the system described strip tension in an annealing line is regulated by a remotely controlled floating roll mounted on a pneumatic cylinder. This method gives quick response and provides a continuous record of tension.—A.G.

The recirculated fresh water system at the Newcastle skelp mill W. T. Longworth (*BHP Tech. Bull.*, 1959, **3,** Sept., 24–29) The economical recirculation of fresh water, with chemical additions, in the cooling system of the new skelp mill is described.—S.H.–S.

The Sendzimir planetary mill: Principle and rolling theory R. Tovini (*Met. Ital.*, 1959, **51,** Oct., 441–461) After a short description of the mill operation the elementary plastic deformation of the slab between the mill rolls is analysed and mathematical ratios are established between slab and strip displacement, deformations, speeds, roll separating forces, torque, and power. The author shows how this theory can be used to calculate mill dimensions and operation. The same theory facilitates study of mill vibrations, strip surface corrugations, mill repelling action, and its inversion and the quantitative evaluation of these factors. Using this theory mill designers and users can carry out a thorough study of planetary rolling technology.

Progress in tube rolling mills in Western Germany Z. Korek (*Hutnik*, 1959, **26,** (11), 449–453) New automatized Pilger rolling mills are described. These roll tubes in the 50–102 mm and 105–529 mm diameter ranges. Extrusion of thin-walled high alloy steels with presses of 1000 t is mentioned. Cold drawing of small dia. seamless tubes with an output of 100000 t per year is described. Finally the author describes modern continuous rolling production methods for tubes of large and small diameters with electrical resistance and induction heating.

The consumption and economy of power in the production of tubes by the automatic and Pilger processes S. I. Borisov (**Stal' Rolling and Tube Manufacture Supplement*, 1958, 314–337) The method used to calculate power requirements was to relate power used to the weight and length of tubing produced, power consumption being calculated using self-recording instruments operating during fixed periods of time, results were obtained from three works. Comparative measurements over a range of tube sizes and wall thicknesses are reported and assessed for the automatic and Pilger processes; the reasons for the greater power consumption in Pilger plants are discussed, and methods of reducing consumption are suggested.

Argentina now makes its own seamless pipe and tubing (*Esso Oilways*, 1959, **10,** (3), 20–21) A brief illustrated account of Dálmine SAFTA.

Boost austenitic strengths by new use for old process M. Fleischmann (*Iron Age*, 1959, **184,** Sept. 10, 181–183) The application of roto-rolling, previously used for the reduction of tubes, to the hardening of austenitic steels is reported. By a reduction in area of around 25% the process gives stainless steel round bars with strengths in excess of 100000 psi.

Heavy sheet metal production at the Longwy plant J. P. Tannery (*Ann. Mines*, 1959, Dec., 760–768) An illustrated account with a table of sizes and thicknesses.

Coefficient of friction and specific pressure in hot-rolling in a vacuum Ya. B. Gurevich and A. M. Zubko (*Stal'*, 1959, (10), 929–931) Absence of scale increases friction and greatly increases resistance to deformation. Flow conditions were observed by indenting the sheet with reference marks.

Studies on the rolling load and rolling torque of a Pilger mill K. Kato (*Tetsu to Hagane*, 1959, **45,** March, 281–283) Data are given for rolling load for various diameters of gas mains, the effect of thickness of the pipe wall on the rolling load, and the relation between rolling load and rolling torque for 12 in. pipe.—K.E.J.

Analysis of bending moments in rolling mill repeaters K. Golembiowski (*Peace Inst. Hutn.*, 1959, **11,** (4), 211–214) Rolling stands should be so designed that their radii of curvature do not cause stresses greater than the elastic modulus of the rolled steel as only then will the minimum bending moment occur.

The roll pass design for the work rolls of a 750/500 mm continuous billet mill I. P. Shulaev (*Stal'*, 1959, (11), 1004–1006) For square and rectangular billets, a pass design combining square and rectangular passes in the first section and diamond and square passes in the second (500 mm) group is described.

A method of comparative assessment of the efficiency of three- and four-roll sets in three-high stands M. L. Mirenskii (*Stal'*, 1959, (11), 1006–1007) The course of roll wear is considered. In a normal set of three rolls only the middle roll is worn out completely, the top and bottom rolls being only half worn. In a four-roll set for a three-high stand, all four rolls are worn equally. This may not, however, always be an advantage and the process of determining this is explained with an example.

Increasing roll life by burnishing A. M. Usov (*Stal'*, 1959, (12), 1110) Axle journals are hardened by the work-hardening effect of contact with rollers or pressures of 1100–1200 kg. The increased wear resistance appears to be due to the smoothing of the shaft rather than to the thin hardened layer.

Effect of C, Si, and Mn on the hardness and strength of ductile cast iron rolls H. Kuroda (*Tetsu to Hagane*, 1959, **45,** March, 227–229) Data are given for the effects of C and Si on 1%Mn and 3%Mn irons. For 1·0–1·5%Mn, linear relationships are shown between hardness and the reciprocal of Si content (1·3–2·3%) for 3·4–3·6%C and 3·7–3·9%C irons.

Effect of reduction ratio on the quality of rolled billets I. Kimura (*Tetsu to Hagane*, 1959, **45,** March, 290–292) Impact and mechanical properties are given for various positions in the billet and reduction ratios up to 20, for SF60 and S841 (killed and semi-killed) steels.

Direct rolling of cast iron T. Kusakawa (*Tetsu to Hagane*, 1959, **45**, March, 275–277) Data are given for electric and Kamaishi pig iron poured molten between water-cooled rolls and rolled into plate. Electric iron poured at 1200°C, with a roll gap of 0·8 mm, gave good results. Physical properties of plate of different thicknesses are tabulated.—K.E.J.

Experience with the rolling of lightened Z-310 sections S. V. Makaev and B. V. Merekin (*Stal'*, 1959, (12), 1099–1102) Sole bars for rolling stock are rolled to smaller thickness so as to reduce the weight of a 60-t wagon by 260 kg, but output is reduced 25% by insufficient power in the mill drive and shorter roll life. By the technique described rejects are only 3–4%.

Rolling of profiles with negative tolerances in Czechoslovakia A. Beran and J. Bláha (*Hutník*, 1959, **9**, (9), 304–305) Rolling of profiles with negative tolerances was introduced on a large scale in three steelworks. This resulted in a reduction of the average weight of beams by 2% below the nominal value, compared with the previous 2% above that value. This resulted in a saving of 1200 t of steel per quarter.—P.F.

The smelting plant of Cie, Forges et Ateliers de la Loire at St. Etienne L. Laravoire (*Mét. Constr. Mécan.*, 1959, **91**, Nov., 793–807) An account of the reorganization and centralization resulting from the fusion in 1953 of four firms, Marine, Firminy, St Étienne, and Jacob-Helzer; with a detailed description of the Marais plant of the St-É. Cie, with bar and wire rolling mills, also roughing and finishing mills is given. A hot ingot car for transport over 15 km is shown.—S.R.–S.

Automatic screwdown gear control system for stands in 900 rail and structural steel mills N. V. Brazhnikov, V. M. Bondarenko, and V. P. Christov (*Stal'*, 1959, (12), 1095–1099) A new installation making use of computers is described. The units of the system are listed and descriptions are given and the operation of the system is outlined.

A stand for side rolling of metals V. G. Dzhidzhieshvili (*Stal'*, 1959, (11), 1008) A design in which two rolls are able to rotate and to move parallel to their axes to impart a cylindrical shape to the billet is described. The billet can be heated by induction. Rectangular shapes can also be rolled.

Controlling sheet billets on the 800 mill by weight, rolling into sheets on the two-high mill V. G. Malinovskii and A. S. Babii (*Stal'*, 1959, (10), 937) A note from Enakievsk. The strength of the rolls fell sharply until the billets were checked by weight of linear length.

Increasing output of a rail and beam rolling mill B. V. Merekin, V. V. Skakun, and G. D. Feigin (*Stal'*, 1959, (12), 1092–1094) A new roll pass design for 800 mm rolls for rolling round and square billets is described.

The significance of the latest technical progress on reconstruction of the rolling mill of an integrated iron and steel works with special reference to the light-section mill train H. Schmieding (*Stahl Eisen*, 1960, **80**, Feb. 4, 150–159) After reviewing the impact of the progress made in electrotechniques and engineering in the last 40 years on rolling mills in general, the author describes the reconstruction of the rolling mill at Salzgitter. This is the second time within 20 years that Salzgitter has built a rolling mill, and layout, design, etc. of the two versions are described in detail, with particular emphasis on the light-section rolling-mill development.—T.G.

Rolling the rack section of a screw-jack B. M. Ryukovich (*Stal'*, 1959, (11), 1000–1003) The skew rolling pass design with uniform deformation over all components of the section in a 250 mm mill is described, which produces the racks with a minimum number of passes and with sufficient precision.

New rod mill steps up output with high-speed twist guides (*Iron Age*, 1959, **184**, Aug. 13, 94–95) The new 10 in. rod mill described is a 23 stand, three strand unit producing rods for reinforcing and wire rope. Novel features include roller twist guides and photoelectric control of crop and cobble shears.—A.G.

Continuous wire-rod rolling mill at Rheinhausen C. Ernst (*Stahl Eisen*, 1959, **79**, Oct. 29, 1674–1677) The author gives some additional information—mainly technical details regarding operation and equipment—to the description of the wire-rod mill by W. Schulz (*Draht*, 1959, **10**, Feb., 41).—T.G.

Scaling of wire rod P. Funke, jun. and W. Lueg (*Stahl Eisen*, 1959, **79**, Oct. 29, 1581–1590) Studies on a number of rolling mills which operate under different conditions showed that the removal of the scale formed during rolling depends much on its structure. It is concluded that modern mills with high rod-speeds usually deliver the rod at higher temp. than did the older models, thus rendering the scale thicker. The effect of cooling not only affects the thickness of the scale but also its structure. Rapid cooling suppresses wustite transformation, which means that the portion of magnetite that can be removed with difficulty remains low. Large coil weights are to be avoided as owing to the lower cooling rates scale formation is heavy and the wustite transformation is also not suppressed.—T.G.

A study on the flat rolling of round wire M. Kuroda, I. Gokyu, K. Yamamori, and T. Watanabe (*Nippon Kinzoku*, 1958, **22**, Nov., 572–576, 576–580) I. Steel and other wires were rolled in a two-high mill. With small reductions, the deformation was localized and the spread small. The greatest specific spread was found with 15–30% reduction in thickness. A formula is given for spread in terms of total reduction in thickness, reduction per pass, roll and wire dial, and wire properties. II. The distributions of hardness and shear stress at various phases of reduction are described.

Modern seamless tube manufacture A. Palmrich (*Prz. Techn.*, 1959, **80**, (37), 15–17) The author describes the manufacture of seamless tubes as well as production and technical details obtained from such a plant in Italy.

Working out the rolling of tubes on the automatic mill with one diameter mandrels and the free return of the tubes over the mandrel by the forward table N. M. Kolpovskii (*Stal'*, 1959, (10), 937) A note from the Lenin Tube Mills. A non-detachable mandrel is being developed to assist complete automation.

Piercing in a cross rolling mill with three driven rolls P. K. Teterin, Yu. F. Luzin, and I. E. Musorina (*Stal'*, 1959, (12), 1099–1102) The advantages of three over two-roll mills are discussed. Axial rupture of the billet and laminations on internal surfaces are prevented. The wall thickness is very constant and power consumption is lower.

Basic problems in the theory of piercing F. A. Danilov, A. Z. Gleiberg, and V. G. Balakin (**Production of steel tubes by hot rolling*, 1954, Chap. 6, 58–93) The calculations and expressions for the forces exerted and power required are given. Piercing rate and billet engagement are also dealt with.

Increasing the life of mandrels for cold tube reducing mills I. Yu. Korobochkin, N. E. Protskii, and O. S. Vil'vams (**Stal'*, *Rolling and Tube Manf. Supp.*, 1959, 154–159) Steels 18KhNVA, 50KhFA, 4KhV25, 40Kh5T, and Kh5TF (compositions given) were tested as the former ShKh15 had short life, numerous defects, and unsuitable microstructure. Steel 50KhFA was best for type 55 and type 80 mills but further studies are needed for material for type 32 mill mandrels.

Experience in piercing and elongating tubes in a three-roll mill S. P. Granovskii, G. S. Marzelis, and N. V. Mekhov (*Stal'*, 1959, (12), 1105–1108) During the development of the three-roll mill piercing process a combined piercing and elongating system was worked out. Wall thickness is very uniform and the internal surface quality is improved.

The prospects of using Pilger mills for pipe cold rolling in Poland Z. Polek (*Hutnik*, 1959, **26**, (10), 413–418) The author compares the advantages of cold-drawn tubes with others and concludes that the demands of the Polish machine, chemical, and other industries justify the enlargement of existing plant.

On the production of N-80 type oil pipes from manganese steel R. Šejnoha and L. Procházka (*Hutn. Listy*, 1959, **14**, (7), 569–573) The production technology of 9⅝ in. diameter steel pipes of ½ in. wall thickness, as developed on the basis of the author's researches is described. The steels contained about 0·44%C, 1·12–1·88%Mn, and 0·1% of Cu, Cr, and Ni respectively. If the tubes are normalized, Mo additions are necessary to assure the prescribed impact strength at low temp.—P.F.

Expanding of tubes E. Střeska (*Hutn. Listy*, 1959, **14**, (10), 856–860) Cross-rolling and other methods used in expanding tubes are surveyed. Improvements which are designed to save steel in the production of tubes of ⅛ in. wall thickness and 20 in. internal diameter are discussed; these are expected to facilitate the manufacture of tubes with thinner walls yet having the same performance as the thicker ones at corresponding temperatures and pressures.—P.F.

Reducing welded tubes in a three-roll stretch reducing mill G. I. Gulyaev (**Stal'*, *Rolling Tube Manf. Supp.*, 1959, 180–187) An investigation into deformations involved in the process is described. An expression is deduced and applied to find various parameters for a series of ingoing and outgoing pipe diameters. A roll pass design derived from the study is given and tests on various tubes are described and discussed.

Lamination susceptibility of boiler plates W. Cias (*Prace Inst. Hutn.*, 1959, **11**, (3), 153–166) Boiler plates made in Poland did not satisfy the Soviet standard GOST 399–41 which considers also the homogeneity of section. The lamination of Polish plates was due to sulphide and oxide inclusions of brittle character.

Transformation of stainless steels in relation to working M. Brocard (*Centre Doc. Sidér. Circ.*, 1958, (6), 1259–1272) Defects observed in rolling stainless steels are discussed and classified as being due to casting conditions or to those prevailing during the rolling operation. The theory and behaviour of 18/8 type stainless steels with or without additions of Ti, Mo, or N are referred to in particular. It is concluded that direct transformation of stainless steel during rolling can be achieved under certain (given) conditions.—R.P.

Influence of low contents of tin on the mechanical properties of cold rolled sheets P. Rocquet, G. Jegaden, and R. Tarriant (*Rev. Mét.*, 1959, **56**, Oct., 249–255) An investigation has been made of the effects of Sn on dead soft cold rolled steel sheets. At 0·2%Sn Rockwell B hardness rises six points and elongation falls four points. Maximum recommended Sn contents for the various grades of the steel tested are given.—A.G.

Improving the surface quality of sheets during pack rolling D. I. Suyarov, A. I. Glushkov, and N. F. Komova (*Stal'*, 1959, (10), 923–925) The causes of surface defects on sheets are discussed and various measures tried are noted. A system for the continuous polishing of work rolls is described which has been most successful in improving surface quality.

Further installations at Lackenby Dorman Long (Steel) Ltd (*Anvil*, 1959, **5**, Autumn, 4–9) An illustrated account of the continuous mills.

Hot stuff at Ebbw Vale Richard Thomas and Baldwins, Ltd (*Anvil*, 1959, **5**, Autumn, 10–12) An illustrated account of the reconstruction of the hot strip mill.

Hot strip mill plans underway G. J. McManus (*Iron Age*, 1959, **184**, Sept. 3, 84–85) A review of projected hot strip mill installations in America is made. Features of these new plants will include more horse power to permit increased hot reduction, automation, and faster strip speeds.—A.G.

Investigating tension in strips when rolling on the 1450 mill V. F. Agapov (*Stal'*, 1959, (10), 936) Brief notes from Magnitogorsk.

Investigation of the automatic control system of the thickness of strip by means of an electron small-scale apparatus S. N. Kozhevnikov and A. P. Pukh (*Izvest. VUZ. Chernaya Met.*, 1959, (7), 127–138) An electronic 'compression-tension' device is described which makes possible the automatic control of the thickness under laboratory conditions.

Sendzimir-type rolling mill stands for the cold-rolling of strip F. Wiesner (*Hutník*, 1959, **9**, (12), 399–404) The advantages accruing from the use of small rolls are reviewed.—P.F.

Hydraulic descaling in strip mills E. P. Karlanski and A. V. Ksennikov (*Metallurg*, 1959, (11), 28) In order to improve the quality

Standardizing rolling on the medium three-high sheet mill by the pressure on the rolls measured by dynamometer V. G. Malinovskii and A. S. Babu (*Stal'*, 1959, (10), 937) A note from Enakievsk. The operation has been shortened by 2-3 passes increasing output 8-3%.

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The consumption and economy of power in the production of tubes by the automatic and Pilger processes S. I. Borisov (**Stal' Rolling and Tube Manufacture Supplement*, 1958, 314–337) The method used to calculate power requirements was to relate power used to the weight and length of tubing produced, power consumption being calculated using self-recording instruments operating during fixed periods of time, results were obtained from three works. Comparative measurements over a range of tube sizes and wall thicknesses are reported and assessed for the automatic and Pilger processes; the reasons for the greater power consumption in Pilger plants are discussed, and methods of reducing consumption are suggested.

Argentina now makes its own seamless pipe and tubing (*Esso Oilways*, 1959, **10,** (3), 20–21) A brief illustrated account of Dálmine SAFTA.

Boost austenitic strengths by new use for old process M. Fleischmann (*Iron Age*, 1959, **184,** Sept. 10, 181–183) The application of roto-rolling, previously used for the reduction of tubes, to the hardening of austenitic steels is reported. By a reduction in area of around 25% the process gives stainless steel round bars with strengths in excess of 100000 psi.

Heavy sheet metal production at the Longwy plant J. P. Tannery (*Ann. Mines*, 1959, Dec., 760–768) An illustrated account with a table of sizes and thicknesses.

Coefficient of friction and specific pressure in hot-rolling in a vacuum Ya. B. Gurevich and A. M. Zubko (*Stal'*, 1959, (10), 929–931) Absence of scale increases friction and greatly increases resistance to deformation. Flow conditions were observed by indenting the sheet with reference marks.

Studies on the rolling load and rolling torque of a Pilger mill K. Kato (*Tetsu to Hagane*, 1959, **45,** March, 281–283) Data are given for rolling load for various diameters of gas mains, the effect of thickness of the pipe wall on the rolling load, and the relation between rolling load and rolling torque for 12 in. pipe.—K.E.J.

Analysis of bending moments in rolling mill repeaters K. Golembiowski (*Prace Inst. Hutn.*, 1959, **11,** (4), 211–214) Rolling stands should be so designed that their radii of curvature do not cause stresses greater than the elastic modulus of the rolled steel as only then will the minimum bending moment occur.

The roll pass design for the work rolls of a 750/500 mm continuous billet mill I. P. Shulaev (*Stal'*, 1959, (11), 1004–1006) For square and rectangular billets, a pass design combining square and rectangular passes in the first section and diamond and square passes in the second (500 mm) group is described.

A method of comparative assessment of the efficiency of three- and four-roll sets in three-high stands M. L. Mirenskii (*Stal'*, 1959, (11), 1006–1007) The course of roll wear is considered. In a normal set of three rolls only the middle roll is worn out completely, the top and bottom rolls being only half worn. In a four-roll set for a three-high stand, all four rolls are worn equally. This may not, however, always be an advantage and the process of determining this is explained with an example.

Increasing roll life by burnishing A. M. Usov (*Stal'*, 1959, (12), 1110) Axle journals are hardened by the work-hardening effect of contact with rollers or pressures of 1100–1200 kg. The increased wear resistance appears to be due to the smoothing of the shaft rather than to the thin hardened layer.

Effect of C, Si, and Mn on the hardness and strength of ductile cast iron rolls H. Kuroda (*Tetsu to Hagane*, 1959, **45,** March, 227–229) Data are given for the effects of C and Si on 1%Mn and 3%Mn irons. For 1·0–1·5%Mn, linear relationships are shown between hardness and the reciprocal of Si content (1·3–2·3%) for 3·4–3·6%C and 3·7–3·9%C irons.

Effect of reduction ratio on the quality of rolled billets I. Kimura (*Tetsu to Hagane*, 1959, **45,** March, 290–292) Impact and mechanical properties are given for various positions in the billet and reduction ratios up to 20, for SF60 and S841 (killed and semi-killed) steels.

Direct rolling of cast iron T. Kusakawa (*Tetsu to Hagane*, 1959, **45**, March, 275–277) Data are given for electric and Kamaishi pig iron poured molten between water-cooled rolls and rolled into plate. Electric iron poured at 1 200°C, with a roll gap of 0·8 mm, gave good results. Physical properties of plate of different thicknesses are tabulated.—K.E.J.

Experience with the rolling of lightened Z-310 sections S. V. Makaev and B. V. Merekin (*Stal'*, 1959, (12), 1099–1102) Sole bars for rolling stock are rolled to smaller thickness so as to reduce the weight of a 60-t wagon by 260 kg, but output is reduced 25% by insufficient power in the mill drive and shorter roll life. By the technique described rejects are only 3–4%.

Rolling of profiles with negative tolerances in Czechoslovakia A. Beran and J. Bláha (*Hutník*, 1959, **9**, (9), 304–305) Rolling of profiles with negative tolerances was introduced on a large scale in three steelworks. This resulted in a reduction of the average weight of beams by 2% below the nominal value, compared with the previous 2% above that value. This resulted in a saving of 1 200 t of steel per quarter.—F.F.

The smelting plant of Cie, Forges et Ateliers de la Loire at St. Etienne L. Laravoire (*Mét. Constr. Mécan.*, 1959, **91**, Nov., 793–807) An account of the reorganization and centralization resulting from the fusion in 1953 of four firms, Marine, Firminy, St Étienne, and Jacob-Helzer; with a detailed description of the Marais plant of the St-É. Cie, with bar and wire rolling mills, also roughing and finishing mills is given. A hot ingot car for transport over 15 km is shown.—S.H.—S.

Automatic screwdown gear control system for stands in 900 rail and structural steel mills N. V. Brazhnikov, V. M. Bondarenko, and V. P. Christov (*Stal'*, 1959, (12), 1095–1099) A new installation making use of computers is described. The units of the system are listed and descriptions are given and the operation of the system is outlined.

A stand for side rolling of metals V. G. Dzhidzhueshvili (*Stal'*, 1959, (11), 1008) A design in which two rolls are able to rotate and to move parallel to their axes to impart a cylindrical shape to the billet is described. The billet can be heated by induction. Rectangular shapes can also be rolled.

Controlling sheet billets on the 800 mill by weight, rolling into sheets on the two-high mill V. G. Malinovskii and A. S. Babu (*Stal'*, 1959, (10), 937) A note from Enakievsk. The strength of the rolls fell sharply until the billets were checked by weight of linear length.

Increasing output of a rail and beam rolling mill B. V. Merekin, V. V. Skakun, and G. D. Feigin (*Stal'*, 1959, (12), 1092–1094) A new roll pass design for 800 mm rolls for rolling round and square billets is described.

The significance of the latest technical progress on reconstruction of the rolling mill of an integrated iron and steel works with special reference to the light-section mill train H. Schmieding (*Stahl Eisen*, 1960, **80**, Feb. 4, 150–159) After reviewing the impact of the progress made in electrotechniques and engineering in the last 40 years on rolling mills in general, the author describes the reconstruction of the rolling mill at Salzgitter. This is the second time within 20 years that Salzgitter has built a rolling mill, and layout, design, etc. of the two versions are described in detail, with particular emphasis on the light-section rolling-mill development.—T.G.

Rolling the rack section of a screw-jack B. M. Ilyukovich (*Stal'*, 1959, (11), 1060–1063) The skew rolling pass design with uniform deformation over all components of the section in a 250 mm mill is described, which produces the racks with a minimum number of passes and with sufficient precision.

New rod mill steps up output with high-speed twist guides (*Iron Age*, 1959, **184**, Aug. 13, 94–95) The new 10 in. rod mill described is a 23 stand, three strand unit producing rods for reinforcing and wire rope. Novel features include roller twist guides and photoelectric control of crop and cobble shears.—A.G.

Continuous wire-rod rolling mill at Rheinhausen C. Ernst (*Stahl Eisen*, 1959, **79**, Oct. 29, 1674–1677) The author gives some additional information—mainly technical details regarding operation and equipment—to the description of the wire-rod mill by W. Schulz (*Draht*, 1959, **10**, Feb., 41).—T.G.

Scaling of wire rod P. Funke, jun. and W. Lueg (*Stahl Eisen*, 1959, **79**, Oct. 29, 1581–1590) Studies on a number of rolling mills which operate under different conditions showed that the removal of the scale formed during rolling depends much on its structure. It is concluded that modern mills with high rod-speeds usually deliver the rod at higher temp. than did the older models, thus rendering the scale thicker. The effect of cooling not only affects the thickness of the scale but also its structure. Rapid cooling suppresses wüstite transformation, which means that the portion of magnetite that can be removed with difficulty remains low. Large coil weights are to be avoided as owing to the lower cooling rates scale formation is heavy and the wüstite transformation is also not suppressed.—T.G.

A study on the flat rolling of round wire M. Kuroda, I. Gokyu, K. Yamamori, and T. Watanabe (*Nippon Kinzoku*, 1958, **22**, Nov., 572–576; 576–580) I. Steel and other wires were rolled in a two-high mill. With small reductions, the deformation was localized and the spread small. The greatest specific spread was found with 15–30% reduction in thickness. A formula is given for spread in terms of total reduction in thickness, reduction per pass, roll and wire dial, and wire properties. II. The distributions of hardness and shear stress at various phases of reduction are described.

Modern seamless tube manufacture A. Palmrich (*Prz. Techn.*, 1959, **80**, (37), 15–17) The author describes the manufacture of seamless tubes as well as production and technical details obtained from such a plant in Italy.

Working out the rolling of tubes on the automatic mill with one diameter mandrels and the free return of the tubes over the mandrel by the forward table N. M. Kolpovskii (*Stal'*, 1959, (10), 937) A note from the Lenin Tube Mills. A non-detachable mandrel is being developed to assist complete automation.

Piercing in a cross rolling mill with three driven rolls P. K. Teterin, Yu. F. Luzin, and I. E. Musorina (*Stal'*, 1959, (12), 1099–1102) The advantages of three over two-roll mills are discussed. Axial rupture of the billet and laminations on internal surfaces are prevented. The wall thickness is very constant and power consumption is lower.

Basic problems in the theory of piercing F. A. Danilov, A. Z. Gleiberg, and V. G. Balakin (**Production of steel tubes by hot rolling*, 1954, Chap. 6, 58–93) The calculations and expressions for the forces exerted and power required are given. Piercing rate and billet engagement are also dealt with.

Increasing the life of mandrels for cold tube reducing mills I. Yu. Korobochkin, N. E. Protskii, and O. S. Vil'yams (**Stal'*, *Rolling and Tube Manf. Supp.*, 1959, 151–159) Steels 18KhNVA, 50KhFA, 4KhV2S, 40Kh5T, and Kh5TF (compositions given) were tested as the former 8hKh15 had short life, numerous defects, and unsuitable microstructure. Steel 50KhFA was best for type 55 and type 80 mills but further studies are needed for material for type 32 mill mandrels.

Experience in piercing and elongating tubes in a three-roll mill S. P. Granovskii, G. S. Marzelis, and N. V. Mekhov (*Stal'*, 1959, (12), 1105–1108) During the development of the three-roll mill piercing process a combined piercing and elongating system was worked out. Wall thickness is very uniform and the internal surface quality is improved.

The prospects of using Pilger mills for pipe cold rolling in Poland Z. Polek (*Hutnik*, 1959, **26**, (10), 413–418) The author compares the advantages of cold-drawn tubes with others and concludes that the demands of the Polish machine, chemical, and other industries justify the enlargement of existing plant.

On the production of N-80 type oil pipes from manganese steel R. Šejnoha and L. Procházka (*Hutn. Listy*, 1959, **14**, (7), 569–573) The production technology of 9⅛ in. diameter steel pipes of ½ in. wall thickness, as developed on the basis of the author's researches is described. The steels contained about 0·44% C, 1·12–1·88% Mn, and 0·1% of Cu, Cr, and Ni respectively. If the tubes are normalized, Mo additions are necessary to assure the prescribed impact strength at low temp.—F.F.

Expanding of tubes E. Střeska (*Hutn. Listy*, 1959, **14**, (10), 856–860) Cross-rolling and other methods used in expanding tubes are surveyed. Improvements which are designed to save steel in the production of tubes of ⅛ in. wall thickness and 20 in. internal diameter are discussed; these are expected to facilitate the manufacture of tubes with thinner walls yet having the same performance as the thicker ones at corresponding temperatures and pressures.—F.F.

Reducing welded tubes in a three-roll stretch reducing mill G. I. Gulyaev (**Stal'*, *Rolling Tube Manf. Supp.*, 1959, 180–187) An investigation into deformations involved in the process is described. An expression is deduced and applied to find various parameters for a series of ingoing and outgoing pipe diameters. A roll pass design derived from the study is given and tests on various tubes are described and discussed.

Lamination susceptibility of boiler plates W. Cias (*Prace Inst. Hutn.*, 1959, **11**, (3), 153–166) Boiler plates made in Poland did not satisfy the Soviet standard GOST 399–41 which considers also the homogeneity of section. The lamination of Polish plates was due to sulphide and oxide inclusions of brittle character.

Transformation of stainless steels in relation to working M. Brocard (*Centre Doc. Sidér. Circ.*, 1958, (6), 1259–1272) Defects observed in rolling stainless steels are discussed and classified as being due to casting conditions or to those prevailing during the rolling operation. The theory and behaviour of 18/8 type stainless steels with or without additions of Ti, Mo, or N are referred to in particular. It is concluded that direct transformation of stainless steel during rolling can be achieved under certain (given) conditions.—R.F.

Influence of low contents of tin on the mechanical properties of cold rolled sheets P. Rocquet, G. Jégaden, and R. Tarriant (*Rev. Mét.*, 1959, **56**, Oct., 249–255) An investigation has been made of the effects of Sn on dead soft cold rolled steel sheets. At 0·2% Sn Rockwell B hardness rises six points and elongation falls four points. Maximum recommended Sn contents for the various grades of the steel tested are given.—A.G.

Improving the surface quality of sheets during pack rolling D. I. Suyarov, A. I. Glushkov, and N. F. Konova (*Stal'*, 1959, (10), 923–925) The causes of surface defects on sheets are discussed and various measures tried are noted. A system for the continuous polishing of work rolls is described which has been most successful in improving surface quality.

Further installations at Lackenby Dorman Long (Steel) Ltd (*Anvil*, 1959, **5**, Autumn, 4–9) An illustrated account of the continuous mills.

Hot stuff at Ebbw Vale Richard Thomas and Baldwins, Ltd (*Anvil*, 1959, **5**, Autumn, 10–12) An illustrated account of the reconstruction of the hot strip mill.

Hot strip mill plans underway G. J. McManus (*Iron Age*, 1959, **184**, Sept. 3, 84–85) A review of projected hot strip mill installations in America is made. Features of these new plants will include more horse power to permit increased hot reduction, automation, and faster strip speeds.—A.G.

Investigating tension in strips when rolling on the 1450 mill V. F. Agapov (*Stal'*, 1959, (10), 936) Brief notes from Magnitogorsk.

Investigation of the automatic control system of the thickness of strip by means of an electron small-scale apparatus S. N. Kozhevnikov and A. P. Pukh (*Izvest. VUZ. Chernaya Met.*, 1959, (7), 127–138) An electronic 'compression-tension' device is described which makes possible the automatic control of the thickness under laboratory conditions.

Sendzimir-type rolling mill stands for the cold-rolling of strip F. Wiesner (*Hutnik*, 1959, **9**, (12), 399–404) The advantages accruing from the use of small rolls are reviewed.—F.F.

Hydraulic descaling in strip mills E. P. Karlanski and A. V. Ksennikov (*Metallurg*, 1959, (11), 28) In order to improve the quality

Standardizing rolling on the medium three-high sheet mill by the pressure on the rolls measured by dynamometer V. G. Malinovskii and A. S. Babu (*Stal'*, 1959, (10), 937) A note from Enakievsk. The operation has been shortened by 2-3 passes increasing output 8-3%.

Increasing the strength of the working rolls on the three-stand cold rolling continuous mill V. F. Agapov (*Stal'*, 1959, (10), 936) A note from Magnitogorsk. Through-hardened rolls were superior to surface-hardened.

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The Sendzimir planetary mill: Principle and rolling theory R. Tovini (*Met. Ital.*, 1959, **51**, Oct., 441–461) After a short description of the mill operation the elementary plastic deformation of the slab between the mill rolls is analysed and mathematical ratios are established between slab and strip displacement, deformations, speeds, roll separating forces, torque, and power. The author shows how this theory can be used to calculate mill dimensions and operation. The same theory facilitates study of mill vibrations, strip surface corrugations, mill repelling action, and its inversion and the quantitative evaluation of these factors. Using this theory mill designers and users can carry out a thorough study of planetary rolling technology.

Progress in tube rolling mills in Western Germany Z. Korek (*Hutnik*, 1959, **26**, (11), 449–453) New automatized Pilger rolling mills are described. These roll tubes in the 50–102 mm and 105–529 mm diameter ranges. Extrusion of thin-walled high alloy steels with presses of 1000 t is mentioned. Cold drawing of small dia. seamless tubes with an output of 100000 t per year is described. Finally the author describes modern continuous rolling production methods for tubes of large and small diameters with electrical resistance and induction heating.

The consumption and economy of power in the production of tubes by the automatic and Pilger processes S. I. Borisov (**Stal' Rolling and Tube Manufacture Supplement*, 1958, 314–337) The method used to calculate power requirements was to relate power used to the weight and length of tubing produced, power consumption being calculated using self-recording instruments operating during fixed periods of time, results were obtained from three works. Comparative measurements over a range of tube sizes and wall thicknesses are reported and assessed for the automatic and Pilger processes; the reasons for the greater power consumption in Pilger plants are discussed, and methods of reducing consumption are suggested.

Argentina now makes its own seamless pipe and tubing (*Esso Oilways*, 1959, **10**, (3), 20–21) A brief illustrated account of Dálmine SAFTA.

Boost austenitic strengths by new use for old process M. Fleischmann (*Iron Age*, 1959, **184**, Sept. 10, 181–183) The application of roto-rolling, previously used for the reduction of tubes, to the hardening of austenitic steels is reported. By a reduction in area of around 25% the process gives stainless steel round bars with strengths in excess of 100000 psi.

Heavy sheet metal production at the Longwy plant J. P. Tannery (*Ann. Mines*, 1959, Dec., 760–768) An illustrated account with a table of sizes and thicknesses.

Coefficient of friction and specific pressure in hot-rolling in a vacuum Ya. B. Gurevich and A. M. Zubko (*Stal'*, 1959, (10), 929–931) Absence of scale increases friction and greatly increases resistance to deformation. Flow conditions were observed by indenting the sheet with reference marks.

Studies on the rolling load and rolling torque of a Pilger mill K. Kato (*Tetsu to Hagane*, 1959, **45**, March, 281–283) Data are given for rolling load for various diameters of gas mains, the effect of thickness of the pipe wall on the rolling load, and the relation between rolling load and rolling torque for 12 in. pipe.—K.E.J.

Analysis of bending moments in rolling mill repeaters K. Golembiowski (*Prace Inst. Hutn.*, 1959, **11**, (4), 211–214) Rolling stands should be so designed that their radii of curvature do not cause stresses greater than the elastic modulus of the rolled steel as only then will the minimum bending moment occur.

The roll pass design for the work rolls of a 750/500 mm continuous billet mill I. P. Shulaev (*Stal'*, 1959, (11), 1004–1006) For square and rectangular billets, a pass design combining square and rectangular passes in the first section and diamond and square passes in the second (500 mm) group is described.

A method of comparative assessment of the efficiency of three- and four-roll sets in three-high stands M. L. Mirenskii (*Stal'*, 1959, (11), 1006–1007) The course of roll wear is considered. In a normal set of three rolls only the middle roll is worn out completely, the top and bottom rolls being only half worn. In a four-roll set for a three-high stand, all four rolls are worn equally. This may not, however, always be an advantage and the process of determining this is explained with an example.

Increasing roll life by burnishing A. M. Usov (*Stal'*, 1959, (12), 1110) Axle journals are hardened by the work-hardening effect of contact with rollers or pressures of 1100–1200 kg. The increased wear resistance appears to be due to the smoothing of the shaft rather than to the thin hardened layer.

Effect of C, Si, and Mn on the hardness and strength of ductile cast iron rolls H. Kuroda (*Tetsu to Hagane*, 1959, **45**, March, 227–229) Data are given for the effects of C and Si on 1%Mn and 3%Mn irons. For 1·0–1·5%Mn, linear relationships are shown between hardness and the reciprocal of Si content (1·3–2·3%) for 3·4–3·6%C and 3·7–3·9%C irons.

Effect of reduction ratio on the quality of rolled billets I. Kimura (*Tetsu to Hagane*, 1959, **45**, March, 290–292) Impact and mechanical properties are given for various positions in the billet and reduction ratios up to 20, for SF60 and S841 (killed and semi-killed) steels.

Direct rolling of cast iron T. Kusakawa (*Tetsu to Hagane*, 1959, **45**, March, 275–277) Data are given for electric and Kamaishi pig iron poured molten between water-cooled rolls and rolled into plate. Electric iron poured at 1200°C, with a roll gap of 0·8 mm, gave good results. Physical properties of plate of different thicknesses are tabulated.—K.E.J.

Experience with the rolling of lightened Z-310 sections S. V. Makaev and B. V. Merekin (*Stal'*, 1959, (12), 1099–1102) Sole bars for rolling stock are rolled to smaller thickness so as to reduce the weight of a 60-t wagon by 260 kg, but output is reduced 25% by insufficient power in the mill drive and shorter roll life. By the technique described rejects are only 3–4%.

Rolling of profiles with negative tolerances in Czechoslovakia A. Beran and J. Bláha (*Hutník*, 1959, **9**, (9), 304–305) Rolling of profiles with negative tolerances was introduced on a large scale in three steelworks. This resulted in a reduction of the average weight of beams by 2% below the nominal value, compared with the previous 2% above that value. This resulted in a saving of 1200 t of steel per quarter.—P.F.

The smelting plant of Cie, Forges et Ateliers de la Loire at St. Etienne L. Laravoire (*Mét. Constr. Mécan.*, 1959, **91**, Nov., 793–807) An account of the reorganization and centralization resulting from the fusion in 1953 of four firms, Marine, Firminy, St Étienne, and Jacob-Holzer; with a detailed description of the Marais plant of the St-É. Cie, with bar and wire rolling mills, also roughing and finishing mills is given. A hot ingot car for transport over 15 km is shown.—S.R.–S.

Automatic screwdown gear control system for stands in 900 rail and structural steel mills N. V. Brazhnikov, V. M. Bondarenko, and V. P. Christov (*Stal'*, 1959, (12), 1095–1099) A new installation making use of computers is described. The units of the system are listed and descriptions are given and the operation of the system is outlined.

A stand for side rolling of metals V. G. Dzhidzhieshvili (*Stal'*, 1959, (11), 1008) A design in which two rolls are able to rotate and to move parallel to their axes to impart a cylindrical shape to the billet is described. The billet can be heated by induction. Rectangular shapes can also be rolled.

Controlling sheet billets on the 800 mill by weight, rolling into sheets on the two-high mill V. G. Malinovskii and A. S. Babii (*Stal'*, 1959, (10), 937) A note from Enakievsk. The strength of the rolls fell sharply until the billets were checked by weight of linear length.

Increasing output of a rail and beam rolling mill B. V. Merekin, V. V. Skakun, and G. D. Feigin (*Stal'*, 1959, (12), 1092–1094) A new roll pass design for 800 mm rolls for rolling round and square billets is described.

The significance of the latest technical progress on reconstruction of the rolling mill of an integrated iron and steel works with special reference to the light-section mill train H. Schmieding (*Stahl Eisen*, 1960, **80**, Feb. 4, 150–159) After reviewing the impact of the progress made in electrotechniques and engineering in the last 40 years on rolling mills in general, the author describes the reconstruction of the rolling mill at Salzgitter. This is the second time within 20 years that Salzgitter has built a rolling mill, and layout, design, etc. of the two versions are described in detail, with particular emphasis on the light-section rolling-mill development.—T.G.

Rolling the rack section of a screw-jack B. M. Ilyukovich (*Stal'*, 1959, (11), 1000–1003) The skew rolling pass design with uniform deformation over all components of the section in a 250 mm mill is described, which produces the racks with a minimum number of passes and with sufficient precision.

New rod mill steps up output with high-speed twist guides (*Iron Age*, 1959, **184**, Aug. 13, 94–95) The new 10 in. rod mill described is a 23 stand, three strand unit producing rods for reinforcing and wire rope. Novel features include roller twist guides and photoelectric control of crop and cobble shears.—A.G.

Continuous wire-rod rolling mill at Rheinhausen C. Ernst (*Stahl Eisen*, 1959, **79**, Oct. 29, 1674–1677) The author gives some additional information—mainly technical details regarding operation and equipment—to the description of the wire-rod mill by W. Schulz (*Draht*, 1959, **10**, Feb., 41).—T.G.

Scaling of wire rod P. Funke, jun. and W. Lueg (*Stahl Eisen*, 1959, **79**, Oct. 29, 1581–1590) Studies on a number of rolling mills which operate under different conditions showed that the removal of the scale formed during rolling depends much on its structure. It is concluded that modern mills with high rod-speeds usually deliver the rod at higher temp. than did the older models, thus rendering the scale thicker. The effect of cooling not only affects the thickness of the scale but also its structure. Rapid cooling suppresses wustite transformation, which means that the portion of magnetite that can be removed with difficulty remains low. Large coil weights are to be avoided as owing to the lower cooling rates scale formation is heavy and the wüstite transformation is also not suppressed.—T.G.

A study on the flat rolling of round wire M. Kuroda, I. Gokyu, K. Yamamori, and T. Watanabe (*Nippon Kinzoku*, 1958, **22**, Nov., 572–576; 576–580) I. Steel and other wires were rolled in a two-high mill. With small reductions, the deformation was localized and the spread small. The greatest specific spread was found with 15–30% reduction in thickness. A formula is given for spread in terms of total reduction in thickness, reduction per pass, roll and wire dial, and wire properties. II. The distributions of hardness and shear stress at various phases of reduction are described.

Modern seamless tube manufacture A. Palmrich (*Prz. Techn.*, 1959, **80**, (37), 15–17) The author describes the manufacture of seamless tubes as well as production and technical details obtained from such a plant in Italy.

Working out the rolling of tubes on the automatic mill with one diameter mandrels and the free return of the tubes over the mandrel by the forward table N. M. Kolpovskii (*Stal'*, 1959, (10), 937) A note from the Lenin Tube Mills. A non-detachable mandrel is being developed to assist complete automation.

Piercing in a cross rolling mill with three driven rolls P. K. Teterin, Yu. F. Luzin, and I. E. Musorina (*Stal'*, 1959, (12), 1099–1102) The advantages of three over two-roll mills are discussed. Axial rupture of the billet and laminations on internal surfaces are prevented. The wall thickness is very constant and power consumption is lower.

Basic problems in the theory of piercing F. A. Danilov, A. Z. Gleiberg, and V. G. Balakin (**Production of steel tubes by hot rolling*, 1954, Chap. 6, 58–93) The calculations and expressions for the forces exerted and power required are given. Piercing rate and billet engagement are also dealt with.

Increasing the life of mandrels for cold tube reducing mills I. Yu. Korobochkin, N. E. Protskii, and O. S. Vil'yams (**Stal'*, *Rolling and Tube Manf. Supp.*, 1959, 151–159) Steels 18KhNVA, 50KhFA, 4KhV25, 40Kh5T, and Kh5TF (compositions given) were tested as the former ShKh15 had short life, numerous defects, and unsuitable microstructure. Steel 50KhFA was best for type 55 and type 80 mills but further studies are needed for material for type 32 mill mandrels.

Experience in piercing and elongating tubes in a three-roll mill S. P. Granovskii, G. S. Maizelis, and N. V. Mekhov (*Stal'*, 1959, (12), 1105–1108) During the development of the three-roll mill piercing process a combined piercing and elongating system was worked out. Wall thickness is very uniform and the internal surface quality is improved.

The prospects of using Pilger mills for pipe cold rolling in Poland Z. Polek (*Hutnik*, 1959, **26**, (10), 413–418) The author compares the advantages of cold-drawn tubes with others and concludes that the demands of the Polish machine, chemical, and other industries justify the enlargement of existing plant.

On the production of N-80 type oil pipes from manganese steel R. Sejnoha and L. Procházka (*Hutn. Listy*, 1959, **14**, (7), 569–573) The production technology of 9¾ in. diameter steel pipes of ½ in. wall thickness, as developed on the basis of the author's researches is described. The steels contained about 0·44% C, 1·12–1·88% Mn, and 0·1% of Cu, Cr, and Ni respectively. If the tubes are normalized, Mo additions are necessary to assure the prescribed impact strength at low temp.—P.F.

Expanding of tubes E. Střeska (*Hutn. Listy*, 1959, **14**, (10), 856–860) Cross-rolling and other methods used in expanding tubes are surveyed. Improvements which are designed to save steel in the production of tubes of ⅛ in. wall thickness and 20 in. internal diameter are discussed; these are expected to facilitate the manufacture of tubes with thinner walls yet having the same performance as the thicker ones at corresponding temperatures and pressures.—P.F.

Reducing welded tubes in a three-roll stretch reducing mill G. I. Gulyaev (**Stal'*, *Rolling Tube Manf. Supp.*, 1959, 180–187) An investigation into deformations involved in the process is described. An expression is deduced and applied to find various parameters for a series of ingoing and outgoing pipe diameters. A roll pass design derived from the study is given and tests on various tubes are described and discussed.

Lamination susceptibility of boiler plates W. Cias (*Prace Inst. Hutn.*, 1959, **11**, (3), 153–166) Boiler plates made in Poland did not satisfy the Soviet standard GOST 399–41 which considers also the homogeneity of section. The lamination of Polish plates was due to sulphide and oxide inclusions of brittle character.

Transformation of stainless steels in relation to working M. Brocard (*Centre Doc. Sidér. Circ.*, 1958, (6), 1259–1272) Defects observed in rolling stainless steels are discussed and classified as being due to casting conditions or to those prevailing during the rolling operation. The theory and behaviour of 18/8 type stainless steels with or without additions of Ti, Mo, or N are referred to in particular. It is concluded that direct transformation of stainless steel during rolling can be achieved under certain (given) conditions.—R.F.

Influence of low contents of tin on the mechanical properties of cold rolled sheets P. Rocquet, G. Jégaden, and R. Tarriant (*Rev. Mét.*, 1959, **56**, Oct., 249–255) An investigation has been made of the effects of Sn on dead soft cold rolled steel sheets. At 0·2% Sn Rockwell B hardness rises six points and elongation falls four points. Maximum recommended Sn contents for the various grades of the steel tested are given.—A.G.

Improving the surface quality of sheets during pack rolling D. I. Suyarov, A. I. Glushkov, and N. F. Komova (*Stal'*, 1959, (10), 923–925) The causes of surface defects on sheets are discussed and various measures tried are noted. A system for the continuous polishing of work rolls is described which has been most successful in improving surface quality.

Further installations at Lackenby Dorman Long (Steel) Ltd (*Anvil*, 1959, **5**, Autumn, 4–9) An illustrated account of the continuous mills.

Hot stuff at Ebbw Vale Richard Thomas and Baldwins, Ltd (*Anvil*, 1959, **5**, Autumn, 10–12) An illustrated account of the reconstruction of the hot strip mill.

Hot strip mill plans underway G. J. McManus (*Iron Age*, 1959, **184**, Sept. 3, 84–85) A review of projected hot strip mill installations in America is made. Features of these new plants will include more horse power to permit increased hot reduction, automation, and faster strip speeds.—A.G.

Investigating tension in strips when rolling on the 1450 mill V. F. Agapov (*Stal'*, 1959, (10), 936) Brief notes from Magnitogorsk.

Investigation of the automatic control system of the thickness of strip by means of an electron small-scale apparatus S. N. Kozhevnikov and A. P. Pukh (*Izvest. VUZ. Chernaya Met.*, 1959, (7), 127–138) An electronic 'compression-tension' device is described which makes possible the automatic control of the thickness under laboratory conditions.

Sendzimir-type rolling mill stands for the cold-rolling of strip F. Wiesner (*Hutnik*, 1959, **9**, (12), 399–404) The advantages accruing from the use of small rolls are reviewed.—P.F.

Hydraulic descaling in strip mills E. P. Karlanski and A. V. Ksennikov (*Metallurg*, 1959, (11), 28) In order to improve the quality

of rolled stock, increase production and lighten the amount of labour required, a special installation has been put into service at the Krasny Oktyabr plant for the hydraulic descaling of rolled strip. The installation comprises the following: (1) a high pressure accumulator consisting of six tanks of 1150 l capacity each; (2) electropneumatic contact control, comprising accumulator control (release valve), electropneumatic control of three circulatory valves and a distributor; (3) a water tank with quartz filters; (4) six high pressure pumps; (5) two, three-stage high pressure compressors; (6) two magnet valves; (7) two distributors supplying water to the collectors; (8) ten collectors for hydraulic descaling.—R.S.

Development and current state of the Krieglach Works of the Osterreichisch-Alpine Montangesellschaft V. Domes (*Berg. hüttenmänn. Monatsh.*, 1959, **104,** Oct.–Nov., 202–208) The history of this cold-rolling and tube-welding mill is described. It was founded in 1838, after the last war it was dismantled, the present cold-rolling train started work in 1952. The welding of tubes from strip started in 1955. Details of the operation of the two mills are presented.—T.G.

Works experience with modern designs of thickness gauge in the cold-rolling mill R. Hinkfoth (*Neue Hütte*, 1959, **4,** Aug., 478–484) Results obtained with three types of thickness gauge are compared and tabulated. No single type shows an overall advantage, but the instrument working on the pneumatic principle appears to be the most promising, due largely to its robust construction.

Cold rolling research and theoretical methods of determining roll pressure in the cold rolling of strip P. O. Strandell (*Jernkont. Ann.*, 1959, **143,** (11), 725–766) A critical review of the development of rolling theories; various methods for the theoretical calculation of rolling force in cold strip rolling are discussed (64 refs).

Considerations on the method of obtaining cold rolled strip of good surface quality and mechanical characteristics L. Daneilli and L. Cocciolo (*Met. Ital.*, 1959, **51,** April, 145–153) The writer examines the heavy reductions of cross-section on cold-rolled strip and considers the best annealing temperatures for obtaining the required mechanical characteristics for cold-forming. The study is extended to normal and high quality steel sheet. For normal sheets the best cold-forming properties are obtained by reduction of at least 70% compared with from 30–70% for high quality steels. Reductions of about 10% should not be made as, after annealing, these cause severe grain growth by recrystallization. The best annealing temperature for good cold-forming proved to be 720°.

Torsional vibrations in drives of Pilger mills A. Čermák (*Hutn. Listy*, 1959, **14,** (10), 864–871) A detailed analysis is made of the nature and origin of the vibrations, which are a main cause of fractures in Pilger mills. Principles of mill-drive design, in which the vibrations are reduced to a minimum and/or made aperiodic, are discussed.—P.F.

Electronic scale records accurate weights of I-beams (*Iron Age*, 1959, 184, Aug. 6, 82–83) I-beams up to 2500 lb in weight are weighed on the hot bed rails by means of four load cells producing both a dial reading and a printed record. The system is said to be both robust and accurate and requires only routine maintenance.—A.G.

Methods and equipment for measuring the thickness and width of hot and cold rolled strip G. Münch (**Stahl Eisen*, 1959, **79,** Oct. 29, 1601–1615) A comprehensive, illustrated review of existing equipment for measuring the thickness and width of hot and cold rolled strip by X- and γ-rays and by contact, magnetic, pneumatic, and optical methods. The main fields of application and the accuracy obtainable are discussed.—T.G.

The elastic-plastic bending of round bars and its application to straightening in three-roll straightening machines O. Pawelski and W. Lueg (*Stahl Eisen*, 1959, **79,** Dec. 10, 1852–1862) The mechanisms involved in the straightening of round bars by elastic-plastic bending is analysed mathematically, the bending strain for an elastic-ideally plastic body was calculated under the assumption of single axial stress. The formulae derived were applied to straightening operation in three-roll machines. From these studies it was possible to derive the best arrangement of the rolls and their camber. Trials on machines equipped with devices for measuring the forces and revolutions involved showed good agreement with theory.—T.G.

The new institute for the working of metals at the Technische Hochschule Aachen O. Schulte (*Stahl Eisen*, 1959, **79,** Dec. 10, 1867–1869) History, layout, and equipment of the new institute for the working of metals at the Technische Hochschule Aachen is described with particular emphasis on the experimental rolling mill and various draw-benches.—T.G.

MACHINERY AND SERVICES FOR IRON AND STEEL PLANT

Application of cushioning material under crane rails K. D. Cunningham (*Iron Steel Eng.*, 1959, **36,** June, 99–100) Padding under the rails of ore bridges has reduced impact stresses by 30% and prevented wearing into grooves of the girder flange surfaces. Experience in the use of these pads and the underlying theory are discussed.

Rail clamp provides greater safety for cranes and ore bridges F. Hoagly (*Blast Fur. Steel Plant*, 1959, **47,** June, 613, 650) The clamp is held by spring-operated serrated jaws to the rail, and several of the clamps have been installed on new structures; they are said to be satisfactory when applied to structures subject to 100 mph winds.

Study on welded iron and steel works crane bridges of the box-girder type: a contribution to the calculation of thin-walled box-girders O. Schindler (*Stahl Eisen*, 1959, **79,** Dec. 24, 1924–1932) The author compares the various types of crane design in common use and gives calculations of forces, pressures, and bending moments of thin-walled box girders. Strain measurements carried out on a box-girder crane are reported. Impact and vibration behaviour of the box girders and cranes incorporating them are discussed.—T.G.

Stress distribution as the basis for the correct design in crane construction W. Kloth (*Stahl Eisen*, 1960, **80,** Feb. 4, 159–164) Stress analysis with the aid of brittle lacquers and electrical strain gauges is used to determine the stress fields and stress distribution in structural parts of cranes with particular emphasis on the avoidance of stress raisers and the like.—T.G.

Evaluation of the operation conditions of steelworks cranes and an assessment of their ratings O. Svenson and W. Schweer (*Stahl Eisen*, 1960, **80,** Jan. 21, 79–90) The authors carried out measurements on box-type crane girders with the aim of checking the static calculation on which the design was based, and on cranes in actual use. They found that the present day design basis provides sufficiently high safety factors, this applies particularly to box-type girders.—T.G.

Standardizing the main parameters of metallurgical cranes G. M. Nikolaevskii (*Vestnik Mashin.*, 1959, (8), 31–35) The opinion is advanced that it would be of advantage to standardize the construction of the different types of cranes according to a uniform specification so as to do away with the variety of constructions now available.

The trend of crane control, for industrial cranes G. V. Sadler (*Mech. Handling*, 1959, **46,** July, 395–398).

How hydraulic systems benefit from simple maintenance (*Iron Age*, 1959, **184,** July 23, 63–65) The advantages of the early detection and remedying of faults in hydraulic systems are stressed. Methods of such fault detection are described together with recommended action.

Avoid hydraulic breakdowns with improved filtering W. Kasten (*Iron Age*, 1959, **184,** Sept. 17, 110–111) Sources of contamination in hydraulic systems are briefly mentioned and a description is given of a special two-micron filter composed of phenolic resin discs.—A.G.

What's new in material handling (*Steel*, 1959, **144,** June 1, 92–95) Recent trends in handling equipment are reviewed, the accent being on more versatile trucks and automatically controlled storage handling systems.—A.G.

Annual reviews: Materials handling. I. Conveyors A. Vierling (*TDIZ*, 1960, **102,** Jan. 11, 69–72). **II. Cranes** H. Ernst (73–75) Deals with improvements and new developments in conveyor systems and reviews briefly some new plant erected during 1959 (48 refs), and then with the latest trends in crane design, for instance the application of three-phase current drive, and describes some new equipment in iron and steel works and for ore handling (81 refs).—T.G.

The use of magnets for materials handling L. J. Hoefkens (*Mech. Handling*, 1959, **46,** July, 382–384).

Transport of sheet material by vacuum lifters and magnets F. Franzen (*Stahl Eisen*, 1959, **79,** Nov. 26, 1803–1807) The author describes the use of vacuum lifters, the production of the required vacuum the employment of many individual magnets in magnetic lifters, and, finally, gripping tongues operated by compressed air, which is drawn from the compressed-air mains of the works.—T.G.

Electrical control of lifting machinery M. Bizot (*Techn. Mod.*, 1959, **51,** Special No. July, Part 1, 9–18). **Speed regulation of AC hoisting winches** J. D. Dufroy (19–22). **Automation in the field of materials handling** Y. Loge (23–27). **Indexed conveyors** (28–30) The King and Cypak systems are described. **The technology of continuous materials handling machinery** R. Jacquot (31–38). **Monorails and overhead travelling cranes** J. Vuillemin (39–50). **Fork lift trucks: characteristics, choice of model and potential uses** M. Sablière (51–54). **Travelling cranes: general features, classification, technical characteristics, safety devices and uses** B. Deboude (55–66). **Adjustable storage units and connecting bridges** J. Charpentier (67–68). **Lifting and handling machinery in steelworks. I.** P. Parratte (69–78) Raw materials, blast-furnaces, steelworks, ingot strippers, and rolling mills are reviewed from the point of view of materials handling with illustrations and plans. Details of layout and mechanisms are then discussed. **Harbour cranes** M. Flinois (79–84). **Weighing and materials handling** (85–96). **Descriptions of some recent achievements** (97–108).

Six-point plan for better material handling C. G. Nolan, W. A. Zarbis, and T. J. Murrin (*Iron Age*, 1959, **183,** May 28, 105–108) In planning a new transformer plant the following objectives were set: justification of any investment in handling equipment, optimum plant location, and layout for handling freight and materials, the elimination of double handling of consignments, use of force flow handling wherever possible and the reduction of storage areas by efficient scheduling.—A.G.

Statistical evaluation of failures of electrical equipment in iron and steel works for reducing breakdowns K. H. Lopitzsch (*Stahl Eisen*, 1959, **79,** Sept. 3, 1273–1280) The author reviews the kinds and manner of failures of the electrical equipment occurring frequently in iron and steel works, and the concepts and methods of statistics to recognize the time factor in breakdown behaviour of the various types of equipment. The statistical evaluation permits certain predictions and therefore enables the necessary steps to be taken to prevent the failure. A lively discussion followed the presentation of the paper.—T.G.

An example of the use of power reserves at a metallurgical works L. A. Kalashnikov (*Stal'*, 1959, (11), 1045–1047) Use at an OH shop of the heat of exhaust gases, waste steam and cooling water reduced fuel consumption for steam production by a factor of ~4½. The development of the waste heat recovery systems is described and further advances are foreshadowed.

Changes which occurred in the generation of electric power and blast in the top-gas power station of an iron works equipped with a 14-MW gas turbine A. Weyel, G. Rabel, and H. Bonner (**Stahl Eisen*, 1959, **79,** Oct. 15, 1471–1478) The considerations which led to the installation of a gas turbine for the generation of electric power and blast in the Klöckner Works, Haspe, are discussed. Construction and erection of the gas turbine on site and a few items of its running in are described.—T.G.

Experience in the use of two gas-turbine plants in Belgian iron and steel works E. Aguet (**Stahl Eisen*, 1959, **79**, Oct. 15, 1479–1483) Design and operation of two gas-turbine plants in Belgian iron and steel works are described. They are the plant of the Société Métallurgique Hainaut-Sambre at Couillet having two 7·5 MW turbines and that of the Société Anonyme Cockerill-Ougrée at Seraing having one 7·5-MW turbine. All three units were built by Sulzer, they are described in detail, their common features are pointed out as well as their differences. The reasons for employing a slightly different design are discussed.—T.G.

Development and design of gas-turbine plants on the basis of thermodynamical theory and the performance limits imposed by the present state of technology H. Pfenninger (*Stahl Eisen*, 1959, **79**, Oct. 29, 1555–1567) This is a review of the development of gas turbines as used in iron and steel works from the first in 1951 to the latest design. During this period the thermal efficiency has increased from 17·5 to 26%. Design and construction of modern gas-turbines for various purposes in iron and steel works are described, the advantages offered by the employment of an air preheater are discussed at length. Another point of discussion was whether it is more advantageous to run the turbine at constant rpm—as in the case of power generation—or to alter the rpm as in the case of blast generation.—T.G.

Station for the purification of the return water system at the 'Stankolit' Works G. D. Pavlov (*Lit. Proizv.*, 1959, (6), 7–8) The return water containing suspended matter picked up in air cleaning and in the scrubbers, and carrying also a percentage of moulding clay is purified so as to be returned to the supply. The plant consists of two sand settling tanks, one mixing tank, a separation tank, four clarification tanks, a reservoir of clean water and pumps, also two slaking tanks, and pumps. The operation of the station is shown diagrammatically.

LUBRICATION

Study of rolling oil K. Saeki (*Toyo Kohan*, 1956, **4**, Dec., 1–9) Lubricants for cold-rolling were compared. The rate of friction increase as a steel ball slides repeatedly over the same track on a rolled strip surface was measured and from this the residual thickness of lubricant on the strip after rolling was estimated at 10 mol layers.

How to get more for your lubrication dollar (*Iron Age*, 1959, **184**, Aug. 20, 126–140) The aspects treated are: the planning of a lubrication programme, the role of the lubrication engineer, selection of the appropriate lubricants, keeping lubricants clean, and methods of application.—A.G.

Stability of position of equilibrium of a journal on an oil film M. V. Korovchinskii (**Akad. Nauk SSSR—Inst. Mashinovedeniya. Trenie i iznos v mashinakh–Sbornik XI*, 1956, 264–323) A review of the theory of Stodola and its developments and a new formulation and complete mathematical development of a new conception of the problem are given. The conditions under which the elementary theory and this new approximate theory give the same values from the linear approximations suggested are defined. Methods of obtaining the necessary parameters are indicated.

Lubrication of the hot deformation of metals B. Jaoul and J. Séjournet (*Mét. Corr. Ind.*, 1959, **34**, June, 221–235) Problems of lubrication under pressure are examined theoretically the advantages of lubrication by glasses are discussed, and an example of the application of glass lubrication is given.

WELDING AND FLAME CUTTING

Improving the welding technology and the thermal treatment of carbon steel wires G. P. Sakhatskii and R. M. Shirokovskii (*Avtom. Svarka*, 1959, (2), 76–86) Tests have shown that various methods of welding have no special advantages over contact resistance welding carried out under strict conditions. Among these would be the minimum duration of the operation. The subsequent thermal treatment is of the utmost importance and a special apparatus ATO has been constructed to carry out automatically the required treatment.

Welding of steel of great thickness without chamfering the edges for hydrotechnical equipment V. F. Doncheko (*Svar. Proizv.*, 1959, (2), 35–37) Automatic welding of 20–50 mm thick metal is simple and highly efficient. The standard welding equipment may be used for welding metal up to 50 mm thickness without bevelled edges. This apparatus is available in most works and does not require operatives with special training. These welds have given good service.

Surfacing brass on to ferrous metals using a gaseous flux G. A. Asinovskaya, E. V. Belova, and N. M. Zelikovskaya (*Svar. Proizv.*, 1959, (2), 28–31) The gas-producing flux consists of a light vaporizing organic liquid containing 66–75% methyl borate in MeOH. A special apparatus is described. The process which was evolved for this operation gives a welded-on metal with a stable high compactness with uniform composition and properties. The strength of the joint of brass on steel is 36 kg/mm² (fracture of brass) and on cast iron 15 kg/mm² (fracture of cast iron).

Effect of the flux on the properties of the welded joints of high strength steels K. V. Lyubavskii, B. N. Bad'yanov, and G. F. Chepelyugin (*Svar. Proizv.*, 1959, (2), 23–25) A comparison of fluxes of different activity in the welding of the high strength 30 KhGSNA steel has established a relation between oxygen content in the joint and impact strength. Best results have been obtained with the non-oxidizing ceramic flux type FTsK. The uts obtained with joints of 15KhGSNA steel attains 115 kg/mm²—with a high impact strength (about 10 kg/cm²).

Welding joints for pipes of 1 Kh18N9T and Kh18N12M2T steels P. A. Orekhov (*Svar. Proizv.*, 1959, (3), 38–39) Different methods of welding are suggested with diagrams and explanations.

Butt welding in a carbon dioxide atmosphere of rotating pipes of low carbon steel A. I. Akulov, V. V. Spitsyn, and A. K. Krzhechkovskii (*Svar. Proizv.*, 1959, (3), 6–7) In 1956 a method for the automatic arc welding of the butts of rotating pipes and turbine units without the use of rings was evolved. The welding is effected simultaneously by two electrode wires separated by the electrode. The welding zone and the fused metal of the welding pool are shielded from the action of the air by a current of CO_2. This method has given good results.

Selecting the most suitable welding process for sulphur cast iron B. G. Ivanov (*Svar. Proizv.*, 1959, (4), 34–40) A detailed list is given of the available welding processes and a list of the composition of the electrodes. This is followed by a classification of the defects and damages of the parts with suggestions of suitable processes for each case.

Build-up of parts by alumino-thermic fusion, 'Fusalurgy' L. Gascuel (*PACT*, 1959, **30**, Oct., 402–403) The process is illustrated by the example of joining two large steel cylinders. Parts not weldable by other means can be repaired in this way giving a sound joint free of segregation.—A.G.

Low-alloy silicon–manganese steels used for structural weldments A. Ya. Brodskii (*Avtom Svarka*, 1959, (5), 45–54) Type 15GS steel with medium C content and a concentration of Si approaching the lowest limits set by GOST 5058–57 cannot be considered satisfactorily weldable, but with a minimum C and Si content it has good weldability. The type of steel within the GOST 5058–57 standards will have no great future for welding.

Automatic welding of components made of 1Kh18N9T steel for short time service at elevated temperatures E. Yu. Yuganson (*Avtom. Svarka*, 1959, (1), 53–57) The high-Si Mn flux AN–348A in a mechanical mixture of 5–10% of Al and iron alloy elements can be used for the automatic welding of this steel. The oxidation of Ti and Cr occurs however in the weld pool. If 5–10%Al is added to the low silicon flux AN–26 the oxidation of Ti is completely eliminated. Increasing the silicon and Mn content in the weld metal and using the mechanical mixture of the AN–348A flux with Al the resistance of the weld metal to scale formation is increased by a factor of 2–2·5.

Automatic welding of petroleum plant made of two layers of steel sheet A. G. Fonin (*Svar. Proizv.*, 1959, (4), 30–32) Improvements in the welding carriage type TS–17M have made it possible to introduce on an industrial scale the welding under flux of two steel sheets with the electrode between them into a bimetal plate. The process gives good quality welds.

Special features of butt welding low-carbon steel strips subjected to subsequent rolling N. S. Kabanov (*Svar. Proizv.*, 1959, (4), 25–30) To avoid the hardening of the metal on the butts which occurs with upsetting, a new butt-welding process has been tested which provides for the entire upsetting to be made under welding current, but limits the pressure by means of the supports between the fixed and movable plates of the welding machine. In this method the welding current is cut off a certain time after completing the operation. The duration of the upsetting is controlled by a time relay.

Electrode holder BEZ 250, for welding without burns S. I. Kirichenko and M. L. Fukel'man (*Svar. Proizv.*, 1959, (5), 40–41) An electrode holder ensuring a semi-automatic striking of the arc to maintain the needed gap in order to produce a reliable contact between the work-piece and the lower end of the electrode; at the moment of welding the operator is shielded from the arc.

Problems related to the home production of fluxes and wires for submerged arc welding and surfacing J. Wegrzyn (**Przeglad Spawalnictwa.*, 1957, **9**, (3), 82–84) A review of the composition of acid and alkaline manganese-free fluxes and of fluxes with Mn, with and without CaF_2, and of the production of these fluxes by the Welding Institute.

Experience with the production of flux in large electric furnaces G. D. Samoilov (*Avtom. Svarka*, 1959, (3), 83–92) The productivity of electric furnaces increases in proportion to their capacity. The quality of the flux improves with an increase in the capacity of the furnace. Contamination of the flux by the electrode mass is not observed. The loss by combustion of the burden materials is reduced by 30–25% with an increase in the volume of the furnace, and the productivity of the furnace depends on its lining. Up to 500 t of flux may be produced in a 5 t electrical furnace.

Isothermal and low-temperature welding of hardenable steels J. Lombardini and A. Tesár (*Zvár. Sbornik*, 1959, **8**, (3), 284–292) In weld repairs, embrittlement may often be avoided if the formation of a martensitic structure, and zones of high triaxial stresses can be avoided. This may be achieved by welding with preheating above M_s, and subsequent annealing until the austenite has fully decomposed, using times given in appropriate TTT curves. Alternatively the joints may be designed to allow only the minimum heat transfer to the base metal; artificial cooling may be used. The scope and application of both methods in practice are discussed.—P.F.

Arc welding of stainless to carbon steels I. N. Gerasimenko (*Avtom. Svarka*, 1959, (2), 59–65) The influence of temperature between 20–1200° on the strength and plasticity of austenitic weld metal is investigated as well as the relation between its mechanical properties and the tendency to crack formation. Results for four types of steel are tabulated.

Automatic welding with unshielded arc of chromium–nickel austenite-stable steels B. I. Medovar, A. N. Safonnikov, and L. G. Puzrin (*Avtom. Svarka*, 1959, (2), 94–95) The investigations have proved the possibility of welding automatically austenite-stable Cr–Ni steels with bare electrodes with an unprotected arc. Wires were used which give a single-phase austenitic or two-phase seams without ferrite (austenite + original carbides, austenite + eutectic). It is claimed that this method will find wide uses because of its simplicity. The usual welding wires can be used with a uniform rate of feed of electrodes and the usual generators as used for welding under flux.

Methods of welding chromium–molybdenum steels P. de Marneffe (*Rev. Soudure*, 1958, **14**, (2), 67–73) The welding of quenching steels used in the oil industry is discussed with par-

ticular reference to steels containing 2–5%Cr and 0·5%Mo. The principles and methods of application of homogeneous and heterogeneous welding are compared and structures of transition zones are described. The use of a new electrode containing 50–70%Ni is advocated for joining ferritic to austenitic materials.—R.P.

On the welding of Ni W V and Ni V types of rotor steels J. Škriniar (*Zvár. Sbornik*, 1959, **8**, (3), 379–419) [In Slovak] The technology and materials required in welding turbine rotors were studied. Suitable conditions, and appropriate electrodes and heat treatments, are recommended.—P.F.

The flash butt welding of grey cast iron L. Hütter and H. Neumann (*Giesserei*, 1959, **46**, Dec. 31, 1001–1007) It is shown that the difficulty of welding grey cast iron parts together is due mainly to their low hot-workability, and that by taking this fact into account a satisfactory weld can be made.

The welding of tool steel J. C. Chyle (*Dansk. Tekn. Tidsskr.*, 1959, **83**, Nov., 227–233) The welding of water-, oil-, and air-hardening steels is discussed, and examples are given of the repair welding of these materials.

Seam welding of butts with cover plates of low-carbon steel S. K. Sloizberg, B. M. Nekrasov, and E. M. Mihkailova (*Avtom. Svarka.*, 1959, (7), 17–20) Low-carbon steel 1–4 mm thick was butt-welded between steel strips 0·2 mm thick and 5–6 mm wide supported on point clamps. The operation was done on the MSHP–150 machine fitted with a PISH–100 interruptor. Optimum welding conditions are tabulated.

Manual electro-slag welding O. Žákavec (*Zváranie*, 1959, **8**, (12), 364–370) [In Czech] In the hands of properly trained, reliable, welders the method is shown to be most suitable for certain applications, e.g. rails. The technology of the process and the properties of welds made by it are considered in the light of tests made by the author.—P.F.

The scope of automatic electro-slag welding M. Mosný (*Zváranie*, 1959, **8**, (12), 356–359) [In Slovak] Joining of straight plates, the preparation of circumferential seams and longitudinal welds in rolled vessels, the welding of rotor shafts and applications in repair work are discussed. The process is versatile and efficient; the quality of the welds is high.—P.F.

On the problem of the electroslag welding of cast iron Yu. A. Sterenbogen and Yu. N. Zaitsev (*Avtom. Svarka*, 1959, (2), 92–93) Investigations of the welding of cast iron components were undertaken at the Paton Electrical Welding Institute. Special welding fluxes have been evolved and the results of the tests show that electroslag welding can be widely used for welding cast iron weldments and for repairing defects on such machine parts.

Working out a new technology for the electro-slag welding of boiler casings of AK medium alloy steel A. M. Makara, I. V. Novikov, V. A. Lutsyuk, G. V. Nazarov, and V. I. Ryabinkin (*Avtom. Svarka.*, 1959, (4), 55–65) A method has been studied for preparing the boiler shell in sections and welding these by means of strips fitting in special gaps. The technical and economic indices of this method of making boiler shells has saved metal, labour costs, and time. Details are supplied with diagrams and comparison tables with the normal process.

Electroslag welding with separated edges V. I. Rabinovich (*Avtom. Svarka*, 1958, (11), 85–89) It has been shown experimentally that joints of good quality can be made with electroslag welding with incomplete weld penetration of the butt joints with separated edges in the form of a cup. It may thus be used in complicated weldments where welding cannot be used without chamfering.

Electro-slag welding of the blast furnace jacket (*Avtom. Svarka.*, 1959, (7), 91–92) An apparatus A–501M is described which can be lifted by a 75-t crane, and special cross-beams with which all welding operations can be carried out at much greater speeds and in a very much shorter time.

Electro-slag welding of low-alloy type M steel S. A. Ostrovskaya (*Avtom. Svarka*, 1959, (8), 25–40) A process of electro-slag welding of type M steel is described at thicknesses of 70–160 mm with a high resistance of the metal to crystallization cracking, good shape welds, and increased efficiency. Wire electrode SV–10GZ is to be used. The weld metal after the operation and high heat tempering has a good impact strength at temp. between +350 and −10°C. After normalization and high-temp. tempering these properties persist down to −60°.

Heat treatment of electro-slag welds J. Vrtel (*Zváranie*, 1959, **8**, (10), 304–309) [In Czech] Heat treatments are discussed on the basis of the author's experience and current Soviet practice.—P.F.

Special feature of butt welding by fusing heat-resistant austenitic steels E. S. Slepak and A. S. Gel'man (*Svar. Proizv.*, 1959, (5), 20–24) The mechanical properties of good welded joints of boiler tubes, of heat-resistant austenitic steels, not heat treated, are similar to the corresponding properties of the base metal. Long-term strength of these joints is also similar to that of the base metal. With prolonged use, a considerable equalization of the microstructure in region of the butt occurs while the mechanical properties of the joint and base metal change uniformly. The chemical composition of the joint depends on the condition of welding.

Special features of the inoculation of welded joints of medium alloy steels with titanium in automatic welding K. K. Khrenov, L. A. Poznyak, Yu. A. Yuzvenko, and M. S. Samotryasov (*Lit. Proizv.*, 1959, (6), 6–8) In the welding of medium-alloy steels the modification of the structure, so as to increase resistance to crack formation and mechanical properties, may be carried out by introducing the inoculating agent in the pool which at the same time prevents overheating. The welded joint should contain 0·008–0·018%Ti. Ti may also be introduced through the electrode but only when heat cracks have to be guarded against, and when a reduction of the plastic properties is of no consequence.

Contact welding for ferrous metal sheets A. M. Kogos, B. A. Ryss, A. S. Gel'man, and N. S. Kabanov (*Lit. Proizv.*, 1959, (7), 34–39) Two butt welding machines for welding strip are described, also incorporating burr cutters, and experiments carried out at different metallurgical works have proved their usefulness. The average welding cycle jointly with burr cutting amounts to 1·1·5 min. On the 1600 machine strips 80–1400 mm wide and 2·5 to 3·5 mm thick are welded.

Projection welding of hot-rolled steel A. S. Gel'man, E. S. Slepak, S. M. Lashchiver, and P. V. Munrikov (*Svarochnoe Proizv.*, 1959, (7), 19–22) Experiments have shown the efficiency of projection welding of untreated hot-rolled steel surfaces from 1·5 mm thickness and over, to give a good quality weld of increased strength with cylindrical electrodes with a large contact surface.

Pistol for holding sheet components at welding spots A. S. Cherkasov (*Lit. Proizv.*, 1959, (8), 42) A device is shown which at one end holds the electrode and at the other a hand lever which switches on the current through timing device. The latter disconnects the current after a given time interval.

Spot welding of steel without preliminary surface preparation V. S. Fel'dman and M. A. Motyakhov (*Lit. Proizv.* 1959 (8), 41–42) At the Vniiptuglemash Institute a new method of welding has been worked out in which in addition to the normal 4–12 V current of mains frequency a 4000–6000 V current of high frequency (∼100000 c/s) is fed from the usual oscillator. Welding at high-frequency takes much less time than that under normal conditions.

Adapting the spot welding machine for welding blades of high speed steel to cutting tools S. G. Khenin (*Svar. Proizv.*, 1959, (8), 37–38) The welding is carried out with the MTP-75–9 spot welding machine. Drawings and explanations for the welding of different types of blades are given, and optimum conditions worked out. Thus, for example welding blades less than 6 mm thick with an area below 200 mm² is done with a current of 380–220 V.

Highly resistant weld seams produced by the automatic welding of 30KhG8A steel under carbon dioxide gas N. I. Kakhovskii (*Avtom. Svarka*, 1959, (5), 22–27) A Cr–Mn steel electrode wire must be used for welding this steel in thicknesses exceeding 6 mm. To produce weld seams with a higher UTS and impact strength, Cr–Mn–Mo steel electrode wires must be used.

Welding with the electric arc rotating in a magnetic field N. Ya. Kochanovskii, E. S. Feder, and S. M. Katler (*Lit. Proizv.*, 1959, (8), 1–4) A new electric arc welding method is described in which the arc rotates in a magnetic field. This method renders unnecessary the use of welding heads moving along the joint and so simplifies automation. Furthermore the arc rotating in a magnetic field facilitates the welding of fixed butts of tubes of a wide range of wall thicknesses and diameters. It also does not require very large sources of current.

Condenser butt welding of 1Kh18N9 steel of small cross sections D. M. Shashin and N. Yu. Pal'chuk (*Lit. Proizv.*, 1959, (9), 19–21) Reducing the welding time from 0·1–0·08 to 0·1–0·04 sec. increases resistance to corrosion of the welding joint in this steel. Condenser flash welding of thin-walled tubes was not found satisfactory but condenser resistance welding gave good results. This method of butt welding can only be used for tubular elements ($d = 3$–$15M$, $\delta \geq 0{\cdot}3$ mm) with very exact centring and careful preparation of the ends.

Plasma heating in welding processes K. V. Vasil'ev and A. A. Isachenko (*Svar. Proizv.*, 1959, (9), 5–6) The chemical composition of the plasma stream is determined chiefly by the composition of the gases blown through the arc discharge. Thus pure mono- and diatomic gas plasma may be obtained: A, N, H, He, and a mixture of gases. The specific action of the stream as a source of heat makes it suitable for use in various processes connected with fusion of high m.p. metals and non-metallic substances.

The arc plasma stream as a source of heat in the treatment of materials I. D. Kulagin and A. V. Nikolaev (*Svar. Proizv.*, 1959, (9), 1–4) The electrode materials are vaporized by the arc and the vapours are ionized while moving near the electrode forming a luminous plasma stream up to 20 mm long. Temp. varies from ∼10000° 2–3 mm from the electrode to ∼6000–8000° at 6–8 mm. A special holder is described which allows operating very near the electrode and the stream can thus be used for welding thick materials, for coating certain components or for soldering in an A-arc flame. The special plasma heads may also serve for local treatment of weld joints, for melting high m.p. substances, etc.

Some features of the processes in the gas-phase of welding under ceramic flux D. M. Kushnerev (*Lit. Proizv.*, 1959, (8), 8–11) The free energy of the reaction, without taking into account the concentration of the reacting substances, is not always a criterion in determining the influence of the flux components in the lowering of the partial pressure of H_2 in the gaseous phase. Experiments have shown that in welding under ceramic flux there is an additional cause of the reduction of the partial pressure of H_2. These fluxes on a marble base give an appreciably lower H_2 content in the weld metal than fluxes with approximately the same content but calcined at 700°C.

The repair by welding of haematite iron castings in iron and steel works C. C. Elster (*Schweissen Schneiden*, 1959, **11**, Dec., 480–482) The repair of the large haematite iron castings used in iron and steel works is described. Welding rods of a carefully alloyed cast iron containing 3·27%C, 3·20%Si, 0·42%Mn, 0·35%Ni as the core are employed. The results of actual welds in the iron and steel industry and the economics of the process are discussed.—T.G.

Experience with cold welding of cast iron V. P. Ryabinkin and S. V. Rul'kov (*Svar. Proizv.*, 1959, (2), 37–42) Schedules are given for the operation on different cast iron components according to a classification and examples given of the work accomplished. As a result, the cold electric arc welding method of repairing cast iron components has proved

efficient. In one works alone in 1957 four heavy cast iron units were repaired with a saving of over 600000 roubles.

The use of welding for the repair of structures P. Richter (*Schweissen Schneiden*, 1960, **12**, Jan., 19–22) A number of applications of repairs by welding are described and illustrated. Structures of grey cast iron, plain C steels, and alloy steels are dealt with.—T.G.

Problems relating to materials and welding in the construction of core reactors W. Gerritsen (*Lastechniek*, 1959, **25**, Dec., 311–319) This article is in two parts, the first concerning Al and the second ordinary steels. In the latter case the procedure to be adopted is discussed for the welding of steels of considerable wall thickness clad on one side with austenite or else with stainless steels. Reference is made to the method of multi-pass welding, sigma welding, and welding under a layer of protective powder or in an argon atmosphere.—F.R.H.

Vertical hydraulic 10000 ton press reconditioned by welding K. P. Voshchanov (*Lit. Proizv.*, 1959, (8), 26–29) The description of welding repairs to this press describes the first attempt at welding heavy components (104 and 134 t) by heating completely to 450–500° without removing the components from the furnace. The results were satisfactory and in spite of the large quantity of molten metal, it was possible to dispense with all subsequent thermal treatment.

Repairs on 200 ton shears R. Rohan and J. Křístek (*Zváranie*, 1959, **8**, (10), 309–311) [In Czech] Overloading of shears used to cut hot 4 in. square steel blooms led to fracture of the lower cutting edge at its entry to the slide. As delays in replacement, due to non-existence of spares, could not be countenanced, the fractured part was replaced by plates welded separately on to the original piece, and also joined to one another by welding. The repaired shears had been in operation for six months by the time the paper was written.—P.F.

Influence of the surface effect on heating steel bars during contact butt welding A. I. Pugin (*Lit. Proizv.*, 1959, (7), 48–47) A theoretical study of the influence of the surface effect on heat distribution over the cross-section and the changes in the specific resistance of medium alloy steel bars during butt welding. Curves have been plotted of the relaxation; initial active specific resistance to unit volume, heat capacity, and also of the relation of the coefficient of temperature increase to the surface of the heated bars.

The use of ultrasonics in welding G. A. Nikolaev and N. A. Ol'shanskii (*Vestnik. Mashin.*, 1959, (4), 51–55) An apparatus for spot welding is described which operates on the following principle. A magnetostriction transformer fed by a high frequency current from a generator of audiofrequency transforms the electric current into longitudinal mechanical vibrations. The transformer is immersed in a special tank of water. The frequency of the electrical oscillations of the wave guide must coincide with the natural frequency. This ensures its operation by resonance and the production of mechanical vibrations with the amplitude corresponding to a high frequency. This apparatus may also be used for welding non-metallic substances. Its use reduces residual deformation and stresses in weldments.

Welding with fully coated electrodes P. Hrbál (*Zváranie*, 1959, **8**, (11), 344–347) [In Slovak] Welding with fully coated electrodes is shown to be economical from the point of view of electrode consumption, but at present the quality of welds is not high. Further work on the evaluation and possible improvements in the use and quality of such electrodes is now in progress in Czechoslovakia.—P.F.

New austenitic electrodes for welding 1Kh13N18V2B type steels A. V. Russiyan and M. Kh. Shorshorov (*Lit. Proizv.*, 1959, (6), 9–13) Electrodes of type AZh 13–18 and AZh 13–15 have been devized for the purpose. The latter type for the butt welding of pipes with 25–55 mm walls (first layer) and the 13–18 type for other layers. The resistance of the weld metal to cracks has been obtained by excluding boron and by adding small amounts of C (0·14–0·18%) and Ni (1·4–1·8%). Long term strength at 650° was 20 kg/mm² for 2180 h.

Cored electrodes for shielded CO_2 welding L. Lakotoš and T. Koromzay (*Zváranie*, 1959, **8**, (12), 359–363) [In Slovak] A new filled electrode has been developed. The ionizing and slag-forming properties of the filler were found to give a steady arc, and transfer of weld metal to the work piece occurred uniformly in small drops. The electrode developed was found to be superior to any other of similar type on the market, and performed satisfactorily in welding under CO_2.—P.F.

Fluxes for welding structural steels E. Pikna (*Zvár. Sbornik*, 1959, **8**, (3), 310–329) [In Slovak] Two fluxes of low basicity for welding high-strength structural steels were developed and tested under various conditions of welding boiler steel. They were found to be very good when judged on all criterin commonly applied to fluxes.—P.F.

Some experiences gained by customer service at the ESAB Laboratories S. E. Erikson (*ESAB Revue*, 1, 1958, 7–16) Examples are given of failures examined and recommendations made. Problems dealt with include those associated with welding, cracks, slag inclusions, and stresses.—R.P.

Magnetic properties of electro-slag welds M. Mosný (*Zváranie*, 1959, **8**, (10), 301–304) Magnetization and magnetic hysteresis was studied in samples taken from the base material and from electroslag welds in shafts of 200–250-t electric generators. Welding practice leading to minimum differences between the magnetic properties of base metal and welds is discussed on the bāsis of experiments carried out by the author.—P.F.

Weldability tests on austenitic Cr Ni steels and electrodes J. Nemec (*Zváranie*, 1959, **8**, (11), 321–328) [In Czech] Existing weldability tests are surveyed. These are found to be costly, complicated, and generally inadequate. A simple hot bend test, carried out on a standardized weld prepared with a W electrode was found suitable. The specimen is heated to 900 C, and the weld is examined for cracks under a low-power microscope after cooling.

On the weldability of 5%Cr steels containing molybdenum or tungsten V. Pilous (*Hutn. Listy*, 1959, **14**, (10), 895–898) The weldability of steels containing about 0·1%C and either 5%Cr, 5%Cr and 0·5%Mo, or 5%Cr and 1%W was investigated. Carbides separated at various stages of heat treatment of the steel were isolated and analyzed. The steel containing 1%W had about the same weldability, in the pre-heated state, as the steel containing 0·5%Mo; impact and Jominy values were also approximately equal. However, a certain favourable influence of W was observed, and this was ascribed to effects arising from the lowering of austenite stability in the region of the bainitic transformation induced by W.

The effect of titanium additions on the weldability of 17%Cr steel M. Vyklický (*Zváranie*, 1959, **8**, (10), 299–301) [in Slovak] Studies of the effect of Ti additions on the weldability, showed that considerable improvements in the weldability of the steel resulted from amounts of Ti equal in weight to five times the carbon content of the steel, *i.e.* 0·5%Ti max.—P.F.

Selection of the metal and electrodes for weldments for service at low temperatures I. N. Gerasimenko (*Avtom. Svarka.*, 1959, (1), 49–52) With the aid of graphs plotted for different steels showing the variation of the impact strength as a function of temperature (from −190 to +10°) the respective material can be selected without difficulty.

Properties of welded joints of 10KHGN steel M. N. Kraichik (*Svar. Proizv.*, 1959, (6), 16–19) The welded joints made automatically have good deformation properties, high impact strength right up to the critical brittle temp. (−70°C), and are resistant to crystallization cracks. Fatigue strength is also satisfactory. Electrodes of type UONI-13/55 are recommended for this steel.

Investigation of butt welding of carbon and alloy steel wires A. T. Galaktionov and A. A. Fofanov (*Avtom. Svarka*, 1959, (7), 21–26) The quality of the weld of a 6 mm diameter wire during drawing, exerts a large influence on the subsequent treatment of the wire. A special apparatus of type ASP-10 ensures good quality butts for welding. Continuous flash welding produces higher quality butt welds than does resistance welding.

Control and correction of the amount of ferrite in the weld and base metals of joints in austenitic steels A. E. Runov, S. A. Iodkovskii, and N. N. Sashchikhin (*Svar. Proizv.*, 1959, (6), 13–15) A method is described for controlling and correcting the amount of ferrite phase in the production of austenite-ferrite steels. This will prevent crack formation in welding and also coarsening of structure in thermal ageing.

Investigation of low carbon steel welding under carbon dioxide and magnetic flux A. G. Mazel', R. P. Burlakova, and K. K. Khrenov (*Lit. Proizv.*, 1959, (8), 15–17) The flux contains iron powder among its slag-forming constituents, which in combination with CO_2 reduces sputtering appreciably. Welding is carried out with a current of 280–300 amp at 30–36 V with two special circular magnets, one of which could lift 100 g and the other 500 g. The joints produced show good strength and plastic properties without porosity.

Strength of steel during the austenite transformation in welding N. N. Prokhorov, E. L. Makarov, and B. F. Yakushin (*Svar. Proizv.*, 1959, (8), 12–15) The investigation concerned the mechanical properties of steels in thermally treated welding joints at various rates of deformation. During austenitic decay the intercrystalline films have also viscous properties, but these layers increase. The time of relaxation of stress at the grain boundaries is $\sim 10^{-2}$–10^{-6} sec. Therefore the progress of deformation along grain boundaries and intercrystalline failure is only possible at low deformation speeds.

The strength of contact spot-welded hatch covers of open rail trucks A. A. Kazimirov, G. O. Olifer, V. P. Morgun, B. I. Blagodatskii, N. D. Portnoi, and M. M. Lyalin (*Avtom. Svarka*, 1959, (7), 67–77) Hatch covers of bent and stamped profiles of 09G2D steel and spot welded have many advantages over mass produced covers. Their introduction improves working conditions, prolongs the service life of the trucks between repairs, and may be recommended for the 60, 93, and 100 t trucks.

Strength of spot welds of 30KhGSA, 12G12A and E1659 steels completed with electro-thermal treatment G. A. Maslov and B. B. Zolotarev (*Svar. Proizv.*, 1959, (8), 21–26) Spot welding with subsequent electrical thermal treatment in the welding machine produces relatively good mechanical properties for the steels investigated. This thermal treatment eliminates the need for a furnace treatment. This electric heat treatment decreases coarseness of structure in the centre of the spot and in the heat affected zone and reduces residual stresses so that a sharp increase in breaking strength after such treatment does not correspond to the relatively small reduction in hardness (up to 15%).

Experience in preventing crack-formation in corner joints of low-alloy steel G. V. Nazarov (*Svar. Proizv.*, 1959, (5), 36–37) It has been established that the cracks which appear with normal automatic welding of T-joints of low-alloy steel containing 0·12%C are absent if the carbon content is reduced to 0·08–0·10%. Cracks are avoided by applying the first layer with a 2 mm wire electrode at lower temperatures. The method worked out consists of using two initial layers with a 2 mm electrode wire and the remaining layers may be applied as usual with a 5 mm wire.

Investigation of the weldability of heat resistant steels with 12% chromium M. Kh. Shorshorov, V. V. Belov, V. N. Zemzin, and I. D. Smirnova (*Svar. Proizv.*, 1959, (9), 6–10) Under the thermal cycle of welding the heat-affected zone of steels with 12%Cr develops a coarse structure in cooling. Steels with 12%Cr with hardening or alloy elements are less susceptible to variable grain growth in the heat-affected zone, but are thermally unstable and according to the welding conditions are subject to softening in the zones subjected to high-temp. tempering.

Investigating the arc welding of the heat-resistant austenitic EI572 steel V. A. Toropov

(*Svar. Proizv.*, 1959, (9), 11–15) As a result of investigations, special TsT–5–57 electrodes were evolved which impart the same long-term strength to the weld metal as is shown by the base metal (EI–572 steel). At 600° the long-term strength of the weld metal, stabilized at 810°, is 22 kg/mm² (100000 h).

The effect of the ferritic phase on the properties of the weld and base metals at the joints of austenitic chromium–nickel steels A. E. Runov and K. V. Lyubavskii (*Svar. Proizv.*, 1959, (9), 15–19) The ferritic phase in the initial structure of these steels may be the cause of reduction in the long term strength. With the same amount of ferrite and the same process of producing an austenite-ferrite structure, the intensity of the decay of ferrite and consequent coarsening of the metal heated between 550–900° depends chiefly on the change in its chemical composition. The method for the production of the austenite-ferrite metal influences largely the dispersivity of the ferrite decay at temperatures corresponding to the coarsening of the metal and also the ferrite solution during austenitizing between 1000–1250°.

Investigating the properties of type M steels 70–160 mm thick and some questions regarding their weldability S. A. Ostrovskaya (*Avtom. Svarka*, 1959, (5), 3–21) Type M steels of great thickness have the same UTS as 22 K steel but a much higher yield-point at 350°. They may be used for service in the open air because of their greater resistance to coarsening. No anisotropy of their properties can be observed. They have good weldability in any welding process, but are specially suitable for electro-slag welding because of their resistance to crystallization cracks and to overheating.

The effect of ledeburite eutectic in the welded seam zone on the mechanical properties of blanks of R 18 and 45 steels B. L. Aleksandrovich and Yu. I. Ivanova (*Stanki Inst.*, 1959, (10), 36–37) The results of the tests described demonstrate the need for close attention to the electrical conditions of the welding operation so that no ledeburite eutectic is present in the microstructure of the weld zone. In the investigation for torsion the ratio between the ledeburite eutectic present in the weld zone and the torsional moment was not measured.

The scientific investigations carried out by the 'Welding Chair' of the Bauman Moscow Higher Technical School G. A. Nikolaev (*Svar. Proizv.*, 1959, (9), 23–26) A short review is given of the investigations in progress at this Institute among which are, residual strains and stresses caused by welding; new physical welding methods; automatic arc welding; contact welding; gas cutting; quality control of welded joints; working out technological processes and on the technological strength of metals in welding.

The effect of the ferritic phase on the resistance of austenitic welds to hot crack formation M. Kh. Shoroshorov, V. S. Sedykh, N. V. Zemzin, and A. E. Runov (*Svarochnoe Proizv.*, 1960, **33**, (1), 1–4) The critical rate of linear deformation, as the index of resistance to hot crack formation of austenitic-ferritic weld metal (19Cr–12Ni–2Mo) is dependent on the quantity and alloying of the ferritic phase, increasing in proportion to ferrite content (0 to 4·5%) from 8 to 11–12 mm/min. Further increase in the ferrite content up to 12% does not change the tendency to hot crack formation. For 19Cr–9Ni–B weld metal the index rises continuously from 3·6 to 11–12 mm/min for ferrite contents from 0 to 10–16%.—M. T.

The quality of oxy-acetylene joints with particular reference to pipes W. J. Kaufman (*Lastechnik*, 1960, **26**, Jan., 4–13) This article is an extensive study of the mechanical properties of welded joints made in C and Mn steel pipes by the oxy-acetylene method using high-quality wire electrodes. Mechanical tests conducted on the joints gave results that were comparable with or even better than those obtainable with electric or agron arc welding. The paper also contains a survey of other work on the same subject conducted in Switzerland, Great Britain, and the Netherlands. Numerous graphs and illustrations appear in the text and a lengthy discussion concludes the article.

Mechanical properties of welding joints of 10G2SD(MK) steel V. Yu. Shishkin, V. A. Makurin, D. I. Navrotskii, and V. N. Savel'ev (*Svar. Proizv.*, 1959, (3), 12–15) This steel has good weldability and may be used for important structures and for spans over railways, and not only for static but also for vibrating loads, because it has less tendency to stress concentrations than other steels.

Properties of austenitic joints of metal type 1Kh15N25M5 at elevated temperatures V. A. Toropov (*Svar. Proizv.*, 1959, (1), 12–16) Electrodes of this type of metal have given strong weldments and good results in long term fatigue testing up to 650° and up to 100000 h. These electrodes may be used for service at higher temperatures but for shorter service. This welded-on metal after stabilization at 800° for 10 h has the following properties at 650°; yield point $\geqslant$22 kg/mm²; UTS$\geqslant$38 kg/mm²; relative elongation $\geqslant$22%; creep limit at 650° of 4 kg/mm² for 10^{-5} mm; impact strength after ageing 3000 h at 650°$\geqslant$5 kg/cm².

Investigation of the heat-resistance of austenite-ferritic welded-on metal type Kh19–N12M–F V. N. Zemzin, E. M. Pivrik, and N. A. Eroshkin (*Avtom. Svarka*, 1959, (3), 19–31) The weld metal of this type of steel with a limiting content of ferritic phase (2–5%) may be used for welding the joints of stationary power generating machines operating at 600° for a period of 100000 h. The greatest heat resistance is obtained by austenitizing the weld metal after the operation.

The influence of the rate of cooling on the structure of the weld metal type 3 Kh2V8 E. N. Morozovskaya and G. I. Parfessa (*Avtom. Svarka*, 1959, (2), 39–48) Type 3 Kh2V8 steel as weld metal has some valuable properties determined by its microstructure after welding. The structure is conditioned by the starting temperature of the base metal. At temperatures below 200° a martensite structure forms with great hardness and brittleness. Above 700° a pearlite structure forms with reduced hardness. The best properties are obtained with a preliminary heating of the base metal to between 300–600° with an angular troostite-martensite structure with considerable red-hardness and strength.

Study of the carbon distribution in the zone adjoining the seam and in the weld metal K. V. Lyubavskii and M. A. Studnits (*Svar. Proizv.*, 1959, (4), 7–12) A macroscopic investigation of the processes of migration of carbon in the welded joints in austenitic steel and examination of an experimental steel by autoradiography has shown that in the boundary zone between weld metal and base metal in the original condition no redistribution takes place, but a stabilization of the weld at 800° for 20 h brings about appreciable redistribution of carbon because of diffusion from the base metal into the weld metal. The intensity of the diffusion from austenitic steels is determined chiefly by the difference in the chemical composition between the base metal and the weld metal due to the carbide-forming elements.

Intracrystalline liquation of phosphorus in electroslag welding joints on carbon steels Yu. A. Sterenbogen, L. A. Poznyak, and G. I. Parfessa (*Avtom. Svarka*, 1959, (2), 20–27) The parts where phosphorus and sulphur liquations occur coincide. P is unevenly distributed in ferritic zones corresponding to the original crystals. This non-uniformity of distribution may be eliminated by high temperature heating followed by rapid cooling. The intracrystalline phosphorus liquation depends on the carbon content in the seams and on the conditions of crystallization of the metal in the welding pool.

The influence of the chemical composition of austenitic weld metal type 25-20 on the $\gamma \rightarrow \sigma$ transformation B. I. Medovar and Yu. B. Malevskii (*Svar. Proizv.*, 1959, (4), 12–16) These weld metals coarsen appreciably because of the γ–σ transformation due to long heating between 650–875°. This tendency is due to the chemical composition. Mn (up to 4%) does not increase the degree of transformation: M, W, and also Cu increase it. A decrease in the Cr content by 2–4% to 20–21% in the presence of Ni (15–25%) increases the resistance to coarsening at high temperatures. An increase in the carbon content from 0·10 to 0·20% almost completely arrests this transformation. Nitrogen also inhibits the intensive transformation because the of conversion of a portion of the Cr into nitrides.

Investigating hydrogen distribution in welding joints of medium alloy steels with austenitic and ferritic seams A. M. Makara, V. I. Lakomskii, and I. P. Zhovnitskii (*Avtom. Svarka*, 1958, (11), 16–31) A method is proposed for drawing samples from welded joints and for treating them so as to elucidate the distribution of H_2. By means of the quantitative analysis suggested it has been found that the H_2 is distributed practically uniformly along the seams and that its distribution in the cross section of single layers depends on their composition and structure. The H_2 concentration in the volumes adjoining the austenitic and ferritic seams is many times greater than in the base metal. Under equal welding conditions H_2 content in the zone adjoining austenitic seams is about six times that near ferritic seams.

Instrument for measuring long-term welding deformation K. K. Khrenov and I. M. Zhdanov (*Svar. Proizv.*, 1959, (3), 16–18) A photograph and diagram of a deformometer are given which measures the long-term cross-sectional deformation of welded joints and also longitudinally, mainly butt joints. The margin of error does not exceed 0·06%.

Summary of the work of the Scientific and technical section for welding of the Machine Construction Industry in 1958 G. A. Maslov (*Svar. Proizv.*, 1959, (4), 42–44) A short report of the activities of the members at the various plants indicating the subjects on which investigations have been carried out.

Regarding the nature of crystallization cracks in the welding of austenitic steels and alloys B. I. Medovar (*Avtom. Svarka*, 1959, (8), 57–66) From a consideration of the numerous systematic investigations at home and abroad a theory is suggested for the hot failure of austenitic weld seams. It considers the crystallization cracks to be the result of two factors, a metallurgical and a stress factor. On the basis of this theory many investigations are reviewed.

The causes and mechanism of hot cracks in welded seams with a single-phase austenitic structure B. A. Movchan (*Avtom. Svarka*, 1959, (6), 49–65) In welded seams of single phase austenitic structure, hot cracks originate in the solid phase below the crystallization front. Polygonization is one of the principal factors promoting the formation of intercrystalline microcracks. As the columnar crystals grow, selective penetration of low mp elements into the crack occurs resulting in its increase into a macro-defect. The avoidance of reduction in polygonization and the refinement of the columnar structure prevents the development of microcracks.

Damage and susceptibility to notching of the welded joints in high pressure steam mains D. N. Vidman and R. E. Mazel' (*Teploenergetika*, 1959, (10), 39–43) The failure of welded joints in steam mains under high pressure has a brittle character without much plastic deformation. The first foci of failure appear at places of stress concentrations in the weld seam. The cracks appear along the line of fusion in the deposited metal. Decarburizing is observed in many cases near the cracks. A high heat tempering of the mains 273×27 mm of 15 KHM steel after welding reduces the tendency to notching.

Problems of cracking related to the welding of austenitic chromium–nickel steels J. Sebille (*Rev. Soudure*, 1958, **14**, (2), 91–118) The causes and types of hot tearing of welds are discussed. Special emphasis is placed on structure, composition, sigma phase, grain size, and welding conditions. Cold strength is not to be taken as a criterion for strength at elevated temperatures (81 refs).—R. P.

Contribution to the study of cold-shuts in arc-welded areas J. Daivier (*Rev. Soudure*, 1958, **14**, (2), 119–122) Fatigue tests carried out on samples welded by different arc methods are summarized. Fatigue failures are stated to be due mainly to pitting or pinholes. In one case failure was caused by a fold.—R. P.

The influence of hydrogen on the formation of cold cracks in the welding of medium alloy

steels R. A. Kozlov (*Svar. Proizv.*, 1959, (4), 17–22) It has been shown experimentally that there is a quantitative relation between the H_2 content in the weld metal and the formation of cold cracks in the welding joints of medium alloy Cr–Ni steels depending on the equivalent weight of carbon in the base metal. A graph of crack formation plotted against the carbon content may serve as a basis of assessing the H_2 content in the weld metal and assist in selecting the suitable technological measures which will ensure a H_2 content in the weld metal below the permissible limit.

The influence of admixtures on the development of hot cracks in weld metal M. V. Pridantsev and A. S. Astaf'ev (*Svar. Proizv.*, 1959, (3), 18–22) Boron in the electrode wires up to 0·014% increases crack formation. Ce up to 0·042% and Ca up to 0·4 %did not produce cracks. An increasing concentration of Ca also increased the tendency to cracking. Ba up to 0·4% had no influence. Very small amounts of Pb (0·0087%) and Sn (0·0016%) and larger concentrations of sulphur in the electrode wires increase the hot cracking tendency.

Preventing slag inclusions in the annular welding joint during automatic butt welding of gaspipes L. A. Kolpel'man (*Svar. Proizv.*, 1959, (3), 11) The welding of 720 mm dia. gas pipes with 8–10 mm thick walls carried out in the usual way has given many rejects. The operation carried out with a current of 450–550 amp at 47–53 volts at a rate of 42–45 m/h has been altered by reducing the current to 450–500 amp and the voltage to 35–38, when it was found that slag inclusions were not produced.

A new general purpose bronze brazing alloy B. Sixt (*Schweisstechn.*, 1959, **13,** Sept., 97–100) The structure and properties of a 12–14%Sn-bronze are discussed. It is shown that this alloy can be used in the form of drawn wire for various welding techniques.

Experience with oxygen-flux cutting of stainless steels in boiler construction B. I. Smirnov (*Svar. Proizv.*, 1959, (5), 27–30) The mechanization of the manual process of oxygen-flux cutting of stainless steels improves the quality of the surface. The edges of sheets must be cleaned after cutting with emery as is usually done with low-alloy steels cut with gas. The effect of oxygen-flux cutting on the structure of the adjoining region is insignificant.

Saving acetylene in steel cutting M. S. Kerner (*Svar. Proizv.*, 1959, (5), 32–34) The effective strength of the oxy-acetylene flame depends chiefly on acetylene consumption, but the strength does not increase proportionally with the increase in consumption. The effective efficiency of the flame according to N. N. Ryklin increases with a reduction in C_2H_2 consumption. The optimum ratio O_2 to C_2H_2 is 1·7. During the operation the character of the flame changes and becomes oxydizing. An electromagnetic control valve has been designed for such contingencies, which controls the gas supplies, and this is described, with diagrams.

Nitrogen-arc cutting of stainless steels I. S. Shapiro (*Svar. Proizv.*,1959, (5), 30–32) Gas-arc cutting of stainless steels accompanied by arc discharge is effective for thicknesses below 50 mm. The possibility of using N_2 containing no more than 1%O_2 for cutting stainless steels has been shown. This method is cheaper than other methods used at present.

Application and economics of automatic flame-cutting machines K. Schindler (*Schweissen Schneiden*, 1959, **11,** Sept., 374–375) The fields of useful application of flame-cutting machines for shipyards and engineering works are discussed and the economic advantages offered analysed.—T.G.

The influence of mechanical and flame cutting on the weldability of 0·11–0·16%C plain structural steels J. Lombardini (*Zvár. Sbornik*, 1956, **5,** (1), 129–142) [In Slovak] Micrographic and X-ray examinations of welded joints showed that, in comparison with mechanical cutting, flame cutting had no detrimental influence on the weldability, as the metallurgical effects associated with flame cutting are removed by annealing through the heat generated by the torch.—P.F.

Air-arc cutting of austenitic steels E. V. Ronginskii (*Avtom. Svarka*, 1948, (11), 52–56) Cutting austenitic steels up to 25 mm thickness with the electric arc and a compressed air supply has many advantages over O_2-flux cutting. Increased current increases output and reduces electrode consumption per running metre of cut. The problem of recarburizing the cut surface remains to be solved.

Influence of the flux composition on the physical and chemical properties of the slag in the oxygen flux cutting of stainless steels O. Sh. Spektor (*Svar. Proizv.*, 1959, (4), 22–25) On the strength of chemical and petrographic analysis it has been found that in slags formed in the oxygen-flux cutting of stainless steels, Cr is present as oxides if the chromite type. The greatest effectiveness of the process is reached by adding 5–10%Al to the iron powder. The specific heat of combustion of the flux increases and the melting point of the slag which is formed is reduced. Addition of Si–Ca to the iron powders widens the cut. The use of quartz sand as flux reduces the productivity of the cutting operation.

The optimum conditions for oxygen cutting of steel V. S. Il'inskii (*Svar. Proizv.*, 1959, (1), 22–24) The rate of cutting has been related to the thickness as has also the O_2 consumption and formulae are evolved which have been verified in practice. But beyond these calculations the efficiency and quality of the cut depend to a large measure on the purity of the gas.

MACHINING AND MACHINABILITY

Metal cutting research challenge and strategy for the future E. Merchant (*Microtecnic*, 1959, **13,** Oct., 217–228) Problems associated with the machining of newly-developed materials such as high-strength and heat-resisting alloys are discussed, and methods of solving them illustrated by case histories from the various fields discussed.

Research on the causes of machinability divergences in steels O. Weill (*Microtecnic*, 1959, **13,** June, 133–142) Investigations on C, Ni–Cr–Nn and 5Ni–Cr steels showed that, in general, that mechanical properties due to chemical composition or heat treatment are the main factors determining machinability.

Machining costs and their influence on metal cutting practice M. C. Shaw (*Microtecnic*, 1959, **13,** June, 103–112) Various contributory factors are considered and analysed, and illustrative examples given.

Technical workshop information 1959 (*Metaalinstituut TNO, Report No.71*, 1960, Jan., pp.35) [In Dutch] This report contains twelve short notes on work done in mechanical workshops to find the answers to questions arising in practice. Reprinted from *Metaalbewerking*. Titles are: What must the radius of a turning tool be? J. A. Cornelissen; Extraordinary wear and tear phenomena when turning steel with ceramic tools; Investigation on the action of turning breaking tools. W. G. Janssen; Turning removal by taps with bevelled starting ends. E. Vos; Making use of lathe capacity when turning cast iron; the occurrence of a concave surface when flat milling with a knife head miller; The difference in the cutting edge height—the greatest defect of a twist drill; Molybdenum disulphide and the life of tools. M. J. C. Mathijsen; Saw figures. The Gwan Hien: Cheap punch tools; the capacity of an eccentric press. P. J. M. Boes; A dynamometer for measuring punch forces. R. J. F. Smeets.

Investigating the temperature deformation of cutting tools E. V. Ryzhov (*Vestnik. Mashin.*, 1959, (4), 73–74) The results of experiments show that the lengthening of the cutting tool depends on the conditions of the operation and on the materials of the tool. Some suggestions are made as to suitable metals for this purpose.

On external friction on machining ductile metals L. F. Kamskov (*Vestnik Mashin.*, 1959, (5), 59–61) The investigation has shown that in the contact zone of the chips, which the author terms the zone of elastic contact, the ratio of the tangential force to the normal is higher than in the zone of plastic contact; the relative effect of the kinetic force of friction is greater than the force of deformation. It follows that the construction of an efficient cutting tool should produce conditions in which the kinetic friction should be at a minimum.

Study of leaded free-cutting steel IX. On the dispersion and solution of lead in molten steel T. Araki (*Tetsu to Hagane*, 1959, **45,** March, 240–242).—K.E.J.

Study of leaded free-cutting steels. X. Effect of heat treatment and distributed lead content on machinability of leaded steels T. Araki (*Tetsu to Hagane*, 1959, **45,** March, 353–355) Data are given for cutting forces at various speeds, and drilling behaviour of S 50 C, S Cr4, and S Cm 22 steels.—K.E.J.

Contribution to experimental investigation of chip formation and novel resulting theoretical and practical considerations F. Eugène (*Microtecnic*, 1959, **13,** June, 113–119) Comparative investigations of cutting tests and compression tests, and discussion of results obtained with a mild steel.

Rapid machining by turning and milling with hard metal tools L. Tschurf and E. Eder (*VDIZ*, 1959, **101,** Sept. 1, 1189–1196) Influence of cutting speeds attainable for a given tool life in machining capacity is examined, and the importance of the shape of the cutting edge is shown (12 refs).

On the behaviour of ceramic cutting tools when applied in cutting cast iron J. L. Rommerswaal (*Microtecnic*, 1959, **13,** June, 126–132) It is shown that, given suitable working conditions, including a chamfered cutting edge, higher cutting speeds could be obtained, together with other advantages, than with carbide tools.

Investigation of the hard alloy for shaping stainless steel N. P. Golubev (*Stanki Instr.*, 1959, (10), 39) The investigation studied the cutting properties of straight cutting tools of different hard alloys in turning a few types of stainless steels. The findings are tabulated.

Grinding mill rolls on a lathe (*Can. Metalw.*, 1959, **22,** Sept., 34–35) Grinding of small chilled steel rolls for crushing is described.

Problems of grinding on universal grinders W. Buschmann (*Maschinenwelt Elek.*, 1959, **14,** July, 337–340) Experiments are described to show that grinding at low speeds is more economical, provided that the grinder is equipped with a suitable range of speed adjustments.

CLEANING AND PICKLING

Descaling of wire by shot blasting H. Krautmacher (*Wire Wire Prod.*, 1959, **34,** Jan., 50–57, 110–114) A description is given of a German descaling unit employing shot blasting with cut wire. Descaling efficiency is discussed in relation to subsequent die wear and the properties of the treated wire. A cost comparison is made with conventional pickling.—A.G.

Continuous patenting, cleaning and coating of rod R. F. Warner (*Wire Wire Prod.*, 1959, **34,** Jan., 58–60, 115) The major problem in such a continuous process is high speed cleaning which is achieved by using a Wheelabrator shot-blasting unit. Factors affecting shot consumption are listed. The process line described has run for 3000 h with little attention once difficulties in dust collection were overcome.

Continuous patenting, cleaning and coating of rod D. K. White (*Wire Wire Prod.*, 1959, **34,** Jan., 64–70, 45–95) A description is given of a new 18 strand rod patenting, cleaning, and coating line which is laid out in a U-shape. Descaling is by the Wheelabrator system, the merits of which are compared with acid pickling.—A.G.

Recent experience with shot blast cleaning of rod K. J. Sorace (*Wire Wire Prod.*, 1959, **34,** Jan., 61–63) The use of mechanical descaling has given a product suitable for bolt making. Cleaning rates are of the order of 150 ft/min.

Modern continuous finishing system for increasing production economically (*Ind. Heat.*, 1959. **26,** July, 1399–1402) A conveyorized finishing system, handling products of size between small electrical outlet boxes and a 5 ft panel enclosures, comprises a three-stage washer, drying oven, two water-wall paint spray booths, and a baking oven. Surface preparation is done in the washer. All operations are automatic, except for spraying. The overhead conveyor can work at between 3 and 9 ft/min.—K.E.J.

Surface treatment (*Draht*, 1960, **11,** Jan., 19–22) Describes some recent additions to

plant equipment used for grinding and polishing and for the cleaning of metals by the liquid solvent, vapour degreasing and ultrasonic techniques, as shown recently at the sixth EWA at Paris.—T.G.

The removal of rust and scale from steam generators E. Seyb (*Brennstoff-Wärme-Kraft*, 1960, **12**, Jan., 9–13) This is a review of experience with various types of rust and scale removers such as HCl, HCl+inhibitor, phosphates or H_3PO_4 of various concentrations, the effect of hydrazine additions to HCl and the use of complex formers such as ethylenediaminetetra-acetate. The advantages and disadvantages and potential hazards of each method are discussed.—T.G.

Removal of corrosion films from different steels M. A. Tolstaya, S. V. Bogatyreva, and G. N. Gradusov (*Zavods. Lab.*, 1959, (10), 1205–1206) Experiments have shown how it is possible to assess the corrosion of austenitic stainless, and low and medium carbon steels in water at high temp. from the losses in weight after cathodic cleaning of the specimens in different media.

The evolution and analysis of an acid bath for the chemical brightening of stainless V2A steel: I. Studies for the formulation of a brightening bath G. Schmid and H. Steinhausen (*Metalloberfläche*, 1960, **14**, Jan., 1–6) A bath for the chemical brightening of stainless V2A steel was developed on the basis HCl–HNO_3–H_2O–H_3PO_4–CH_3COOH. At a bath temperature of 65°C optimal brightening was obtained after 45 sec. The method of analysis of the bath is presented and the limits of the brightening action can be taken from ternary diagrams.

Some physical, chemical and technological properties of electrolytes for the electrochemical polishing of steel G. P. Maitak and G. S. Tret'yakova (*Zhurn. Prikl. Khim.*, 1959, **32**, (10), 2242–2247) The service life of the electrolyte under test with inhibitor for polishing high-carbon steels is appreciably longer than that of the sulphate-phosphate-CrO_3 electrolyte. The density, viscosity, and electrical conductivity of the freshly prepared electrolyte with inhibitor is practically the same as that of the SO_4–PO_4–CrO_3 electrolyte but it changes less sharply during service; the density and acid viscosity increase at first to fall afterwards but the electrical conductivity uniformly increases.

Pickling agents and pickling F. Margival (*Peint. Pig. Ver.*, 1958, **34**, Sept., 401–444) Various mechanical and chemical pickling methods are considered and compared with special reference to the degreasing and cleaning of metallic surfaces prior to protection. Compositions of suitable pickling solutions are given and some degreasing installations are described. Parts to be cleaned are usually submitted to several treatments, followed by rinsing and drying.—R.P.

Effect of increased iron sulphate levels in sulphuric acid pickles on the technological properties of pickled steel wires C. Eisenhuth and M. Martin (*Stahl Eisen*, 1959, **79**, Dec. 10, 1862–1867) High iron sulphate levels in the pickle reduce the technological properties of the wires, mainly bending and twisting values. High iron sulphate content leads to sludge formation and, in turn, to local-cell formation and consequently pitting. It is emphasized that the pickling operation should be adjusted to the quality of the steel. In view of laws against water pollution it is essential to employ mechanical descaling, to use ion exchange for regeneration of the pickle, or to convert to continuous pickling; the advantages of these three methods are stressed.—T.G.

PROTECTIVE COATINGS

Changes of concentration in electroplating baths A. von Krusenstjern (*Metalloberfläche*, 1959, **13**, Dec., 391–393) Experiments to examine the segregation of constituents of the electrolyte in Cu, Ni, and Ag plating baths are described and discussed.

Treatment of combined finishing wastes A. G. Winger (*Met. Fin.*, 1959, **57**, Nov., 60–63) The system described, based on ion exchange, is used for handling toxic wastes from nearly 20 plating and metal finishing baths at the Bristol, Tennessee plant of Raytheon Co.'s Missile Systems Div. Details of the equipment and its operation are given.

How planning factors cut waste treatment costs C. Civan (*Iron Age*, 1959, **184**, Sept. 24, 124–126) Factors considered in relation to the treatment of effluents from electro-plating and similar processes include the location and type of equipment, space requirements, and the staff needed for operation and maintenance.—A.G.

Plating drums for mass-production electroplating H. von Uslar (*Wire*, 1959, June, 62–64) Examples of modern types of plating drum and their use in mechanized production are described.

Improved chromium plate (*Met. Prog.*, 1959, **76**, July, 113–114) A 'duplex' process has been developed for car bumpers and trim. A bright crack-free plate is covered by a second bright deposit of finely cracked Cr. This disperses cell action over a large area, and reduces corrosion. The total thickness of 0·10–0·20 ml is applied to copper-bright nickel on zinc die-cast or steel parts.—K.E.J.

Nickel plating in a fluoride–borate electrolyte V. I. Lainer and I. I. Panchenko (*Vestnik. Mashin.*, 1959, (5), 65–68) The electrolyte is prepared from the stoichiometric amounts of HF and H_3BO_3. The boric acid is introduced in small amounts into the HF and the vessel is immersed in ice. The cathodic process has been investigated regarding the influence of concentration of the nickel salts, of the boric acid, of the temperature, and regarding the polarization at the anode and cathode and the quality of the deposit. The following optimum conditions are recommended: 80–100 g/l $Ni(BF_4)_2$; 15 g/l $NiCl_2$, 6 H_2O; 10 g/l H_3BO_3; a pH of 3 and a temperature of 50°. Current density up to 20 A/dm² giving an anode and cathode yield of about 100%.

Chemically-deposited nickel alloy provides heat-treatable coating Albright and Wilson (Manfg.) Ltd (*Metalw. Prodn.*, 1959, **103**, Oct. 30, 1747–1751) An illustrated account of the Kanigen process. Properties and uses are noted.

Large gas-radiant-fired kettle improves galvanizing of steel structural products R. E. Buckholdt (*Ind. Heat.*, 1959, **26**, Sept., 1722, 1724, 1726, 1728, 1831) The article describes a new method incorporated in the design of a new galvanizing furnace in operation at the Buffalo Steel Corpn., Tonawanda, N.Y.

Semi-killed steels for tinned and galvanized sheet J. Teindl and B. Otta (*Hutn. Listy*, 1959, **14**, (10), 886–894) Extensive experiments on the works scale showed semi-killed steels to be superior in the manufacture of tinned or galvanized sheet for food preserve tins to rimming steels. Porosity was less and other properties were improved. Erichsen values could be maintained at the same level as for rimming steel by the addition of Si in amounts leading to no more than 0·1%Si in the finished sheet.

The hot-dip galvanizing of tubes A. Hankel (*Metalloberfläche*, 1959, **13**, Nov., 354–356) A general description is given of the preparation and galvanizing process, the subsequent treatment of the tubes, and their corrosion-resisting properties.

The question of the hot-dip galvanizing of wires W. Püngel (*Metalloberfläche*, 1959, **13**, Nov., 351–354) The influence of surface condition of the steel on the structure of the Zn-layer is described. The importance of manufacturing conditions before galvanizing in the case of high-C high tensile wire is emphasized. Fatigue bend tests on plain and galvanized wire rope showed the latter to be more satisfactory for use in damp shafts. Slight improvement in corrosion resistance is obtained by 'Galvannealing' but less satisfactory surface structure and embrittlement of the Zn layer can occur.

The influence of prestresses (residual stresses) on the behaviour of rimmed Thomas steel on hot-dip galvanizing H. Wiegand and F. Nieth (*Metalloberfläche*, 1959, **13**, Nov., 346–350) The behaviour of smooth and notched test pieces of hot-dip galvanized rimmed Thomas steel under static tensile stress was examined. The elastic behaviour and embrittling action of the Fe–Zn alloy layers were determined. In the case of smooth specimens the maximum elongation was greatly reduced, while both maximum stress and elongation were diminished in the notched specimens by the Zn coating.

The thickness of the zinc deposit and the corrosion behaviour of hot-dip galvanizing parts R. Haarmann (*Metalloberfläche*, 1959, **13**, Nov., 342–345) The influence of various factors—steel composition and structure, and galvanizing conditions on the thickness of the Zn deposit is reviewed, and resistance against attack by air, water, and soil discussed. It is often more economical to cover a normal layer of Zn with a coat of paint than to obtain a heavy layer directly by hot-dip galvanizing.

Right methods aid forming of precoated steel tubing Armco Steel Corp. (*Steel*, 1959, **145**, Sept. 21, 87) With appropriate techniques such as heavy lubrication, tight clamping and positioning of the weld, aluminized and zinc coated steel tubes can be readily formed. Possible forming operations are briefly mentioned together with methods of restoring damaged coatings.—A.G.

T. C. & I. feeds tin and black plate mechanically (*Iron Steel Eng.*, 1959, **36**, Nov., 152, 154) Operations are described by which the Tennessee Coal and Iron Division of United States Steel Corp. feeds tin and black plate mechanically to slitters, oiling machines, sheet counters, and tin pots.

Process for pretreating cast iron for hot-dip tinning R. Kuhn (*Giesserei*, 1959, **46**, Aug. 13, 478–480) The operation of the Kolene No.4 salt bath process developed by the Kolene Corp., Detroit is described, in which cast iron articles to be tinned are treated so as to remove graphite from the surface. Examples of cast iron pipe fittings and plain bearings are given.

New method for the hot-tinning of iron M. C. J. Thwaites (*Mét. Corr. Ind.*, 1958, **33**, July–Aug., 335–342) The author discusses and compares the three main methods used, namely: flux method, oxidation of graphite from the surface, and the electro-deposition method prior to tinning.—R.P.

Increased production through electrolytic tinning line modernization D. A. Jenter (*Iron Steel Eng.*, 1959, **36**, Oct., 145–151) An account of the modernization of the No.3 electrolytic tinning line at the Irving Works Plant of United States Steel Corp., by which speed was increased from 700 to 950 ft/min. by modifying existing electrical equipment and fitting it into a new drive and control system.

The influence of rolling technology on the quality of tinned sheet J. Kolofik (*Hutnik*, 1959, **9**, (10), 341–346) It is shown that cold-rolled sheet is more suitable and economical than hot-rolled sheet for the production of tins for canning.—P.F.

Fundamental studies on structure and properties of aluminized coatings carried out in Japan D. Horstmann (*Stahl Eisen*, 1959, **79**, Dec. 10, 1869–1872) This is an authoritative review of work carried out by Saga and his co-workers in Japan on the structure and properties of aluminized coatings, the effect of steel composition, thickness of the sheet to be treated, dipping time, cold working of the sheet, bath temperature, silicon contents, corrosion behaviour, etc.—T.G.

Metallization by spraying with stainless steels (*Aciers Fins Spéc.*, 1955, **33**, Dec., 55–57) The history of metallization is summarized and recent advances in low-temp. spraying of alloy steels are pointed out. Some examples are given.—R.P.

Reclamation by metal spraying W. E. Ballard (*Lastechniek*, 1959, **25**, Nov1, 289–296) [In English] The author describes in detail the best methods of preparing and spraying worn surfaces such as those of journals, shafts, etc. in order to restore them to useful service. He also makes ample reference to work of this nature that has been carried out by investigators in other countries. The spraying of ceramic surfaces is also touched upon and the paper concludes with an extensive discussion in Dutch.—F.R.H.

Conversion coatings—phosphate films L. F. Spencer (*Met. Fin.*, 1959, **57**, Dec., 64–67) Topics considered are: mechanism of coating formation and coating characteristics, and

phosphate coatings as a paint base, for corrosion resistance, and to reduce wear.

Properties and structure of phosphate coatings V. Čupr. (*Metalloberfläche*, 1960, **14**, Jan., 17–18) The author reports on studies of the composition, crystal structure, the changes occurring in the phosphate coating during drying at elevated temperatures and on the changes which are a result of working.—T.G.

Theory of the supplementary process in phosphating baths W. Jaenicke and B. Lorenz (*Werks. Korr.*, 1959, **10**, Dec., 761–767) The relationship between corrosion in secondary surface layer formation in phosphating iron in zinc phosphate solutions was examined theoretically and experimentally. It is shown that the ratio of H_2 consumed and Fe dissolved can be calculated if all reactions are diffusion-controlled, and hence that crystal nuclei are formed rapidly, and Zn and (PO_4) equilibrium remains in adjustment up to the metal surface. Practical applications of the theory are indicated.

Surface protection of cross-country steel pipes by asphalting Z. Halaš (*Hutn. Listy*, 1959, **14**, (10), 875–879) Methods of pipe protection used in Czechoslovakia are discussed, and the principles underlying the assessment of the quality of protective coatings and wrappings are considered.—F.F.

New protective coatings for hot galvanized steel J. F. H. van Eijnsbergen (*Metalen*, 1959, **14**, Dec. 31, 392–396) The author first calls attention to six particular cases where hot galvanized steel needs extra protective coatings and goes on to refer to numerous materials that can be utilized for the purpose. These latter are in the form of varnishes made from a wide range of synthetic resins that have appeared on the market in latter years, i.e. epoxy resins, vinyl-copolymers, acrylates, etc. The required thicknesses of the applied coatings are also touched upon.—F.R.H.

Metal-plastic combination material (*Iron Steel Eng.*, 1959, **36**, Oct., 158–160) Advantages of thermosetting, laminated plastics combined with metal, with types and sizes available are described, with reference to products manufactured by Synthane Corp., Oaks, Pa.

Largest production line for coated steel sheets being installed at Armco Plant (*Ind. Heat.*, 1959, **26**, Sept., 1758) A brief description of a 565 ft long production line which will double the capacity of the works. 72 in. wide strip is coated at 300 ft/min. Capacity of line 30 t/h.

National Steel starts operation of plastic coating line for strip Enamelstrip Corp. *Iron Steel Eng.*, 1959, **36**, Nov., 159) The technique of application and properties are outlined briefly of the decorative, abrasion-resistant plastic coating applied to long coils of steel strip by a subsidiary of National Steel Corp. The coated steel is named 'Miracoil'.

A co-ordinated wire coating line H. J. Bates (*Wire Wire Prod.*, 1959, **34**, Feb., 202–204) The control of wire speed is considered in relation to capstan design. A co-ordinated drive system utilizing adjustable DC voltage is advocated in which the extruder is the master section and the capstan a slave unit.—A.G.

Enamel frits now sprayed electrostatically J. Bauer (*Metalw. Prodn.*, 1960, **104**, Feb. 3, 206) Finishing of washing machines is briefly described.

Some remarks on the quality of steel and cast-iron used for enamelling J. Teindl (*Hutnik*, 1959, **9**, (9), 292–296) The chemical compositions of the alloys are discussed, particularly enamelling irons and steels containing small amounts of Ti. The production economics of enamelling with Ti-bearing enamels are considered with reference to experiments with Czechoslovak 'Behanit' steels. The formation of 'fish-scale' and other defects is considered.

The liquid enamelling of cast iron R. Piva and P. Debouté (*Fonderie*, 1959, Oct., 463–468) The principles governing enamelling tests, their results (with and without annealing) and the influence of moulding are described and the results summarized.—S.H.-S.

Nature of adherence of porcelain enamels to metals B. W. King, H. P. Tripp, and W. H. Duckworth (*J. Amer. Ceram. Soc.*, 1959, **42**, Nov., 504–525) An extensive investigation is reported showing that good adhesion is due to metal-to-metal bonds and requirements of the enamel for this to be possible are given. In the case of iron, FeO is the important oxide. Effects of practical conditions and of surface roughness are also dealt with.

Continuous line provides wide prepainted strip (*Steel*, 1959, **145**, Aug. 24, 88–90) Coiled strip 60 in. in width can now be painted before fabrication by continuous equipment comprising two coaters, ovens and water rinses in series.—A.G.

Metallic lead priming paints for marine usage H. A. Newnham (*Corros. Techn.*, 1959, **6**, Dec., 366–368) Choice of priming paints for different parts of the ship's structure is discussed.

Extra durability of paint on low-alloy steels H. R. Copson and C. P. Larrabee (*ASTM Bull.*, 1959, (242), Dec., 68–74) Field tests and actual experience show paint to be more durable on low-alloy steels than on C steel or Cu-steel with less rust formation and hence less chance of rupture of the paint film. Numerous samples are shown.

Pigments for rust-protection paints K. A. van Oeteren (*Metalloberfläche*, 1960, **14**, Jan., 18–20) The pigments which are most popular for rust protection by paints are discussed. They are red lead and lead cyanamide for the primers and white lead, zinc oxide and aluminium for the final coat. The use of chromates which have only recently been employed is also mentioned.

The behaviour of chrome yellow and natural-gas carbon black in the corrosion protection of iron C. Braniste, D. Peretz, and S. Serban (*Bull. Inst. Iasi*, 1958, **4**, 3–4, 153–160) [In German] The experimental findings show that coatings of natural-gas carbon black afford better protection against moist corrosion, independent of the binder (linseed or linden tree oil) and that khaki colour coatings give a higher degree of protection against corrosion than the individual pigments. Linden tree oil was found more satisfactory than the normally used linseed oil.

Simple instrument for measuring the thickness of ferromagnetic layers on steel K. P. Azarov, V. E. Gorbatenko, and V. N. Krolikov (*Zavods. Lab.*, 1959, (4), 486) The description is given of a pocket thickness-meter with permanent magnet which may be widely used in controlling varnish, enamel, and other coatings on a ferromagnetic base.

CLAD SHEET AND HARD FACING

Diffusion metal coatings of steel from gaseous media by heating with high frequency current Yu. V. Grdina and L. T. Gordeeva (*Izvest. VUZ Chernaya Met.*, 1959, (7), 98–99) The tests described have proved the possibility of applying diffusion coating of metals (Al, Mo, W, Si, and Cr coatings), from gaseous media (the chlorides of these metals) and heating with high-frequency currents. The diffusion rate is greater than that in furnaces by a factor of a few hundreds.

Arc welding process for hard-facing with hard alloys, components exposed to abrasion M. A. Tylkin (*Svarochnoe Proizv.*, 1959, (5), 35–36) At the Dzerskinsk Works, many components such as the lugs on crushing machines, mixer vanes, etc., are now refaced with a welded coat of stalinite. The component is first so shaped that the addition of the hard facing will give the proper contour. This facing is made by fusing the stalinite with a metallic electrode so that the facing layer is an alloy of Cr, Mn, Si, and C.

Experience with diffusion chromiding D. Ya. Speranskii and G. N. Dubinin (*Vestnik Mashin.*, 1959, (7), 71–73) A process of diffusion chromiding is described which ensures a Cr concentration on the surface of 70–90%, of Al of from 3 to 6% and of N a concentration about ten times that of the original steel. The N here forms the carbonitride phase $[Cr_2(CN)]$ which is very thin (5–7 μ) but very strong (> 1500 kg/mm^2).

Surface alloying of steel castings J. Rous (*Slévárenství*, 1959, **7**, (10), 401–404) Surface alloying, which provides a cheap and rapid method of surface quality improvement, was developed for tractor chain links. A 2 mm thick layer containing 11%Mn and 1·2–1·5%C was obtained. Fe–Mn was mixed directly into the core-sand mixtures. The metallography of the surface structure is discussed. The links were found to have a high wear resistance in tests using carbide abrasives.

Protective chromium plating of inside and outside tube surfaces by diffusion G. Becker (*Metalen*, 1960, **15**, Jan. 15, 2–4) The article describes a method of diffusing a chromium halide vapour into the inner and external surfaces of tubes by enclosing them during treatment in a sealed oven at a temperature of ~1000 C. The depth of diffusion depends on the duration of the heat treatment but it is found that a thickness of 0·1 mm provides a good corrosion resistant zone. Tests are described and various practical applications of the process are suggested and illustrated.—F.R.H.

Automatic welding on a layer of chilled cast iron by means of a cast iron electrode tape G. B. Ksendzyk (*Avtom. Svarka*, 1959, (2), 54–58) Iron tape may be used as electrode material prepared by crystallization, i.e. the rolling of the liquid metal. A special flux AN–28 has been evolved for welding on the cast iron tape and the method of welding flat and cylindrical parts has been worked out. The hardness of the chilled cast iron obtained with welding on is 40–50 HRC and its resistance to wear is 3–3·5 times that of structural carbon steels. The efficiency of welding with the cast iron electrode is higher by a factor of approximately 10 than that for manual welding of stalinite (a very hard tool alloy) and much cheaper than the latter.

Hard utility alloys for weld-surfacing of tightening surfaces of high-pressure armatures K. Lobl (*Zváranie*, 1959, **8**, (7), 200–206) The development and testing of new Stellite type alloys in which Co is partly replaced by iron is described. Preliminary tests showed satisfactory performances; the alloys might be suitable for use up to 550°.—P.F.

Concerning the assessment of strength and resistance to wear of electrometallizing steel coatings Yu. D. Pashin (*Vestnik Mashin.*, 1959, (7), 65–67) Electrometallizing coatings have different strengths in different directions and therefore this must not be assessed from their strength parallel to the covered surface. The findings of these tests and the many observations made under production conditions justify the metallization process after repairs of components working under friction or slipping, and working in a medium of oil containing abrasive admixtures.

Experience of hard-facing steel mill rolls at the Nazhne-Tagil iron and steel combine (NTMK) T. N. Bazilevich and N. I. Smirnov (*Stal'*, 1959, (72), 1108–1110) A welding head mounted on a lathe carriage is used in a way described. The electrodes used and the flux supply are given and the machining and properties of the faced rolls are considered. Cheaper grades of weld metal and continuous hardness probes are needed.

Reconditioning crane pulleys by hard facing M. A. Tylkin, V. M. Sivak, I. F. Parfent'ev, and M. A. Kropp (*Svar. Proizv.*, 1959, (5), 25–27) The process consists of the following operations, turning the worn wheel to remove scale; annealing mechanical treatment of the rolling surface; sorbitization; additional tempering and turning the shaft opening.

Effect of welding technique on the wear properties of hard facings K. Wellinger and H. Uetz (*Schweissen Schneiden*, 1959, **11**, Dec., 458–474) Low-alloy and high-alloy filler metals, sintered hard metals and cast superalloys were used for hard facings under a variety of conditions and the wear characteristics of the beads were tested in sliding friction. The effect of the basis metal on the wear properties of the hard facings were also tested. The results are presented in many graphs and tables (25 refs).

POWDER METALLURGY

New uses for powder metallurgy (*Met. Progress*, 1959, **75**, June, 97–99) A process for the continuous compacting of metals and alloys and of ceramics and metals is described, and a method of bonding carbides to steel is outlined.

New powder metallurgy applications in the metal cutting field H. Frommelt (*Proc. 14th Ann. Meeting Met. Powder Assoc.*, 1958, April, 5–8) The use of infiltrated bodies in machining for the reduction of vibration leading to damage to the edge is described. **Mechanical filter transducer wire and resonator discs by powder metallurgy** W. E. Whittington (9–18) Ni–Fe compacts are described. **Metal powder industries year-end report for 1957** K. H. Roll (19–22). **The effect of sintering atmospheres on the properties of sintered iron compacts** E. P. Kawasaki (23–31) Studies on Fe, Fe–7%Cu, Fe–3%Cu–1%C and Fe+C in H_2, endo- and exothermic gas atmospheres are reported. High strength is obtained in a carburizing atmosphere but with a carbon potential above 0·85% the weaker hypereutectoid structure results. **Hydrogen and dissociated ammonia for sintering** M. R. Ogle (32–36) Production and properties are outlined with illustrations of equipment. **Exothermic and purified exothermic atmospheres for sintering** H. M. Webber (37–41) Partially burnt natural gas with or without removal of CO_2 and H_2O is reviewed. **The application of the endothermic atmosphere generator to the sintering of powder metallurgy parts** N. K. Koebel (42–46) The conversion of natural gas to $CO+H_2$ by partial combustion and catalytic reformation is reviewed and the use of the product for sintering Fe and other powders is outlined. **Frontiers of powder metallurgy in the USSR** C. G. Goetzel (47–54) A summary of information on research developments obtained during a visit, mostly non-ferrous. **Present status of the powder metallurgy industry in Japan** J. Miyauchi (55–64) Largely statistical. **Metal powders for barrel finishing** G. C. Madigan (71–78) various abrasives are compared. **Slip casting of metal powders** H. H. Hausner (79–90) The process is described and the properties of stainless steel slip castings are noted. **Fundamentals of powder metallurgy lecture: A new viewpoint on sintering** F. W. Rhines (91–101) The process of sintering is analysed topologically, and densification is considered in relation to diffusion, vapour transport, and plastic flow. **Chromizing of metal powder parts** R. P. Seelig (102–106) A brief survey of the process and its results. **Hot forming techniques for consolidating metal powders** H. H. Hirsch (112–125) Hot forming techniques and equipment are reviewed. Pressing, extrusion, and rolling are described and the properties of the products from Fe and non-ferrous metal powders are given.

On the gas carburizing, quenching and tempering of sintered Fe and Fe–Ni compacts T. Fujiyama (*Sumi. Met.*, 1959, **11**, Jan., 37–50) The compacts were 10×10×55 mm in size, made by single- and double-pressing methods. For single-pressed specimens, carburization proceeds to the core; for double-pressed, only to 1·0–1·2 mm below the surface. The double-pressing method leads to superior mechanical properties (quoted). Ni improves the properties; it is not completely diffused and remains in the matrix.—K.E.J.

Preparation of iron and its alloys in a finely divided condition by electrolysis on a mercury cathode. Application to the study of the hexagonal iron carbide P. Lesage-Bourdon and A. Michel (*Compt. Rend.*, 1959, **249**, Oct. 28, 1675–1677) The highly active powder was reacted with CO–H_2 mixture at 170° for 200–250 h. X-ray and thermomagnetic studies of the products were made.

The quantum formation mechanism of metallic powders by electrolysis with high current densities A. Calusaru and I. Atanasiu (*Studii Si Cercet. Met.*, 1959, (3), 365–376) The phenomena at limiting current are due to the double electric field in the zone, one of zero concentration adjoining the electrode, making specific adsorption impossible and the other in which the ions are neutralized by the electrons which can penetrate because of the high probabilities of passage. In the zone of the limiting current an increase in potential cannot be accompanied by an increase in current and therefore the mean neutralization distance must increase because the probability of a jump increases with an increase in the energy levels of the electrons in the metal.

Electrolytic iron powder from a caustic soda solution J. A. M. LeDuc, R. E. Loftfield, and L. E. Vaaler (*J. Electrochem. Soc.*, 1959, **106**, Aug., 659–667) A slurry of ferric oxide in various concentrations of NaOH was examined. Temperature is important and 90°C and 600–800 g/l NaOH and low dc are recommended. Pilot plant studies confirm this. Properties are given and an easily ground dendritic deposit is formed. Particle size, shape, ductibility flow rate and compactability were examined and also the strength and elongation of sintered compacts.

Investigating fine-dispersion carbonyl iron by means of the electron microscope A. A. Petrova, E. V. Tsvetkova, and V. M. Gorshunova (*Izvest. AN Ser. Fiz.*, 1959, **23**, (6), 687–689) Four qualitatively distinct particles have been found in this investigation of the secondary structure; (1) with a clear 'onion like' structure, (2) with a partly destroyed 'onion-like' structure, (3) without 'onion-like' structure, and (4) with a splinter structure. It was also found that some particles of carbonyl iron are single multi-layer spheroids or agglomerates of these, in layers also surrounding some iron crystals.

New thermo-chemical techniques—2. Powder metallurgical applications P. Galmiche (*Met. Finishing J.*, 1959, **5**, May, 191–195, 204) Production and chromizing of sintered iron parts and stainless steel powder sintering are included.

Production of powder alloys of nickel with iron and with molybdenum by joint reduction of a mixture of these oxides G. A. Semenov (*Zhurn. Prikl. Khim.*, 1959, **32**, (7), 1502–1505) The reduction in H_2 of the oxides of Ni, Fe, and Mo even at the relatively low temp. of 900° ends in the formation of powder alloys. At lower temperatures (600°) the reduction of the oxides to the metal occurs in both these alloys while at higher temp. mutual diffusion takes place.

Cathodic reduction of iron oxide V. P. Galushko, E. F. Zavgorodnaya, and L. I. Tushchenko (*Zhurn. Prikl. Khim.*, 1959, **32**, (7), 1551–1555) The influence of the electrolyte, temperature current density, and the addition of certain substances on the degree of cathodic reduction of Fe_2O_3 was studied. The possibility was demonstrated of producing metallic iron powders by the reduction of Fe_2O_3 in an alkaline electrolyte (40%NaOH) at 80°. It was also found that the cathode reduction proceeds mainly in the solid phase.

Development and present position of powder metallurgy in the German Democratic Republic F. Eisenkolb (*Neue Hutte*, 1959, **4**, Sept., 534–540) Fundamental research, and the development of refractory materials, products for general machine construction and special purposes, and substances with good hot strength are reviewed (113 refs).

Process compacts metal powders into continuous bars F. Emley and C. Deibel (*Iron Age*, 1959, **183**, April 23, 112–113) Powder in a trough-like container is compacted by a sloping punch which by its reciprocating action advances the powder and forms a continuous bar. The bar which may be metal or ceramic is then sintered. The process is only experimental at present.—A.G.

The advancement of powder metallurgy applications in the automobile R. E. Blue (*Met. Powder Ind. Fed.*, 15th Annual Meeting, 1959, 94–98) A general discussion of factors in their introduction.

The utility of sintered alloys produced by the new Mallory process C. Vollers (*Metalen*, 1959, **14**, Oct. 31, 308–309) A brief description of a new process developed in America by P. R. Mallory and Co. Inc. of Indianapolis with particular reference to the physical properties of several types of MoNi, NiMn, stainless, CuNi, and NiCrVSi alloy steels claimed by them to be similar in quality and characteristics and freedom from porosity to the steels produced by conventional methods.—F.R.H.

On the compacting of metal powders S. Ya. Plotkin and G. V. Samsonov (*Vestnik. Mashin.*, 1959, (5), 53–56) An investigation into various problems such as the effect on the strength of the compacted briquettes of different factors, e.g. the time the powders are under pressure, the elastic reactions after compacting, the sequence of compacting etc. The results of this investigation under the different headings and for different metal powders are tabulated.

The mechanism of the compaction of metal powders by rolling P. Evans (*Planseeber.*, 1959, **7**, Dec., 102–116) [In English] The development of powder rolling is outlined, and factors relating to roll design and speed and the size and shape of the powder are examined experimentally and theoretically.

The compacting of brittle powders W. Rutkowski (*Hutnik*, 1959, **25**, (10), 397–402) A study is made of the phenomena occurring during the compacting of powders, and methods of calculating the behaviour of powders during compacting, the different behaviour of brittle and plastic powders during compacting and sintering. It is calculated that the increase in δ^K and μ for hard, brittle, or oxide powders is dependent on: (1) the reduction in the relative density at the same specific pressure as a result of the increased operation of friction and the reduced plastic deformation; (2) the reduction in the density of the resultant powder is *inter alia* due to the reduction in the pressure-tightness of the apparatus and to improper filling of the die due to increased friction between the grains of the powder if the filling and compacting are loosely effected; (3) as a result of resistance to compression and plastic deformation, and in this connexion the formation of areas of contact, the physical properties (e.g. electrical conductivity) of these materials are worse in otherwise equal compacting conditions; (4) during the compacting of brittle powders, fragmentation (embrittlement) of the larger grains of the powder occurs to a greater extent which clearly effects all the properties; (5) the phenomena described work advantageously during the compacting of brittle powders with a large proportion of slip planes in mitigation of the unfavourable influences of the nature of the powder material.—M.T.

Magnetodielectric materials made from carbonyl iron powder M. Waltenberger, L. Siarzewski, and B. Affeltowicz (*Prace Inst. Hut.*, 1959, (1), 41–50) First the manufacturing techniques for magnetic cores of various coils are given. This is followed by description of properties of materials used, methods of insulation, the design of equipment and methods of measurement of magnetic properties. Particular attention was paid to the effects of additions of mica dust. Magnetic properties for K22 type cores are quoted in conclusion.

Sintering in the presence of liquid phases J. Hlavač (*Silikáty*, 1959, **3**, (3), 279–286) Theoretical aspects of sintering of cermets and metal powders in the presence of liquid phases are considered for reactive and non-reactive systems.—P.F.

The thermodynamics and kinetics of sintering H. J. Oel (*Z. Metallkunde*, 1960, **51**, Jan., 53–58) Model experiments are described with the object of explaining the sintering mechanism in single-component systems. It is shown that plastic flow, recrystallization, and internal stresses can play an important part in the early stages of sintering, and that the mechanism of material transport is complex.

Investigations of the principles underlying the sintering process in metal powders taking, into account the influence of surface oxide layers W. Dienst and O. Werner (*Z. Metallkunde*, 1960, **51**, Jan., 45–52) The linear contraction of Fe and Cu powder compacts in the direction of application of pressure was measured with a direct-reading dilatometer, and it was shown that the derived curve of time against contraction corresponded approximately to an exponential function, and that the most probable initial sintering mechanism is plastic flow, followed by grain-boundary diffusion.

The problem of elastic deformation of powders during pressing W. Rutkowski and J. Bryniarski (*Hutnik*, 1959, (4), 154–158) The author considers the problem in detail and draws the following conclusions: The deformation of the product after the removal of pressure varies with the amount of pressure. This effect depends on the fineness of the powder and the finer the powder the greater the deformation. The harder the powder the

greater the deformation. Lubrication makes the process more effective.

Mechanism of sintering W. D. Jones (*Acta Met.*, 1959, **7,** March, 222–223) A letter. It is considered that the difficulty of the theory of densification during the sintering of cubic metals, i.e. that it does not account quantitatively for the initial very high rates of densification, and can be met by assuming extensive grain boundary movements.

Processes involved in sintering R. G. Bernard (*Powder Met.*, 1959, (3), 86–103) The fundamental processes involved in the sintering of pure metals, mixtures, and of substances yielding a liquid phase are reviewed. The need for further investigation based on micro-calorimetric measurements of changes in free surface energy is stressed.—A.G.

The mechanism of sintering in single component systems I. M. Fedorchenko and R. A. Andrievsky (*Powder Met.*, 1959, (3), 147–171) Subjects treated include plastic flow, sintering kinetics, the mechanism of shrinkage, and activated sintering. It is concluded that plastic flow is absent in free sintering when diffusion is responsible for shrinkage. A quantitative explanation of shrinkage requires the development of a theory of non-stationary diffusion.

Recent British developments in the theory of sintering G. A. Geach (*Powder Met.*, 1959, (3), 104–114) The sintering process is discussed with reference to the material sintered, the effect of active additions, the influence of departures from stoichiometric composition, the sintering atmosphere, and the influence of grain boundaries in the later stages of sintering.—A.G.

Current progress in theories of sintering in the U.S.A. J. T. Norton (*Powder Met.*, 1959, (3), 115–124) Recent American work in the field of solid and liquid phase sintering is reviewed. Suggestions are made for future lines of research.—A.G.

Recent work on the theory of sintering in the German Democratic Republic F. Thummler (*Powder Met.*, 1959, (3), 125–145) The possible mechanisms involved in sintering and the primary and secondary factors affecting the process are listed. Research work in East Germany is reviewed.—A.G.

Investment casting or sintered powder L. E. Raymond (*Prod. Eng.*, 1959, **30,** June 8, 86–87) A brief discussion of factors in the choice between thees methods of small part production.

Studies of sintering atmospheres for ferrous products based on the incomplete combustion of methane gas G. Dan, A. Protopopescu, and O. Stefan (*Studii Cercetari Met.*, 1959, **4,** (2), 189–199) With partial combustion of CH_4 a wide range of gaseous mixtures may be obtained. The effect of these gases on compacted iron powders subjected to sintering shows that in concentrations corresponding to an air excess of 0·45 to 0·60 (air/gas ratio 4·5–6·5) sinter does not carburize or oxidize. The mixtures are reducing mixtures, no traces of oxides can be found. The same mixtures can also be used as shielding gases. With high O_2 and CO_2 contents the sintered components become oxidized. They are lustrous and the fine oxides are well dispersed.

A new basis for an inspection method for sintered metal components B. Bovarnick (*Met. Powder Ind. Fed., 15th Annual Meeting*, 1959, 72–81) Electrochemical and tensile tests are described on specially prepared very pure carbonyl iron compacts and their significance is assessed.

The influence of oxygen content on the properties of sintered metals and the zone of contact formed between them W. Rutkowski (*Z. Metallkunde*, 1960, **51,** Jan., 59–61) By means of compacts of Fe and W so made that the metals were in separate halves of the compact, the effects of added oxides during sintering on the properties of the sinter and of the contact zone were investigated.

Electrical resistivity as a measure of the degree of sintering G. Dan and A. Protopopescu (*Studii si Cerceti. Met.*, 1959, (3), 353–364) According to the nature of electrical resistance, changing with rising temp., two zones are distinguished. A first zone up to 500°C characterized by a substantial fall in resistivity with increasing temp. and a second between 500–1100° in which resistivity varies less but the changes are continuous. The rapid fall in resistivity is probably due to the oxide films and the formation of metallic contact; the slower changes at higher temp. correspond in a certain degree to an increase in density.

Principles and methods of powder statistics A. Vidmajer and R. Brenner (*Radex Rund.*, 1959, (6), Dec., 734–760) A mathematical treatment is given of the statistics of powder and particle properties. Aspects of the application of statistical methods to the examination of disperse systems are discussed; particle properties are discussed with respect to weight, volume, surface, size, and range, and their relationship to analogous powder properties is dealt with. General mathematical properties of statistical relationships of powders and their range of application are considered, and this is followed by a mathematical discussion of the Resin and Rammler law and the logarithmic Gaussian law, from the points of view dealt with in the earlier part of the article.

FERRITES, CERMETS, AND CARBIDES

Kinetic studies on zinc ferrite formation T. Yamaguchi and T. Takei (*Sci. Papers Inst. Phys. Chem. Res. Tokyo*, 1959, **53,** June, 51–65) [In English].

Electric resistance and cation distribution of Fe–Mn ferrite system Z. Funatogawa, N. Miyata, and S. Usami (*J. Phys. Soc. Japan*, 1959, **14,** June, 854) [In English].

Fundamentals of metal-ceramic combinations (cermets) (*Metals for supersonic aircraft and missiles. Proc. Conf. Albuquerque*, 1957, *sponsored by ASM and Univ. New Mexico, ASM publication*, 1958, pp.432) H. H. Hausner (315–339) Sintering and the properties of multiple component systems are outlined and components and structures of cermets are reviewed. Properties of various carbide cermets are given (19 refs). **Specific ceramics and cermets of promise** M. F. Judkins (340–352) Oxides, carbides, and some proprietary cermets, borides, silicides, and nitrides are reviewed.

Influence of an addition of chromium carbide to sintered hard metals V. Dufek (*Neue Hütte*, 1959, **4,** July, 425–428) Experiments are described from which it was found that an addition of up to 1%Cr_3C_2 had a beneficial effect, hardness and resistance to oxidation being increased. This was particularly noticeable in high-Co alloys (18 refs).

Carbides of elements of the fifth group of the periodic table bonded with steel M. Epner and E. Gregory (*Planseeber*, 1959, **7,** Dec., 120–128) [In English] Experiments with the carbides of V, Ta, and Nb bonded with C steel showed that all the carbides responded to heat treatment and were machineable in the annealed condition. The properties of the cermets are discussed.

X-Ray study of ferromagnetic domains in cobalt zinc ferrite K. M. Merz (*J. Appl. Phys.*, 1960, **31,** Jan., 147–154).

Observations on the structure and sintering mechanism of cemented carbides J. Gurland (*Trans. Met. Soc. AIME*, 1959, **215,** Aug., 601–608) The structure of sintered WC–Co and TiC–Co alloys has been investigated by dilatometric and metallographic methods. It is concluded that sintering involves the transport of particles through the liquid binder followed by grain growth and coalescence.—A.G.

The properties of $NiFe_2O_4$–$MgFe_2O_4$ solid solutions N. A. Smol'kov and Yu. P. Simanov (*Izvest. AN Seriya Fiz.*, 1959, **23,** (3), 307–310) The investigations covered the structural, magnetic, and high-frequency properties of nickel magnesium ferrites of stoichiometric composition. The specimens were prepared from the oxides sintered for 3 h at 1300°. The results of the X-ray analysis, of the static magnetic characteristics and of high frequency measurements are given.

Investigation of the magnetic properties of the NiO–ZnO–Fe_2O_3 system K. A. Piskarev (*Izvest. AN Seriya Fzi.*, 1959, **23,** (3), 289–303) X-Ray analysis was used for the investigation. The systems were selected by the lines from the corners of the triangle of the constitution diagram, and intersecting the 50% mol Fe_2O_3 concentration of two components. The Curie points were investigated for various compositions as well as the initial magnetic permeability and the specific magnetization.

The preparation of manganese ferrite. I. Ignition in air A. Bergstein, M. Rozsival, and M. Mikulaš (*Coll. Czechoslovak Chem. Comm.*, 1959, **24,** March, 885–895) Phase composition, crystallite form, ferromagnetism, and Curie point as functions of ignition temperature are determined for two compositions.

Temperature change and disaccommodation of the initial permeability in the system MnO–ZnO–FeO–Fe_2O_3 W. Heister (*Tech. Mitt. Krupp*, 1959, **17,** May, 82–89) The anomaly (frequent appearance of a second maximum) in the change with temperature of the initial permeability of Mn–Zn ferrites with excess Fe is discussed. The relationship of disaccommodation to iron oxide content and sintering temperature is measured, and activation energy is determined from the disaccommodation and the magnetic angle of retardation (8 refs).

Preparation of the ferrites $BaFe_{12}O_{19}$ and $SrFe_{12}O_{19}$ in transparent form L. H. Brixner (*J. Am. CS*, 1959, **81,** Aug. 5, 3841–3843) Internal domain structure is visible in polarized light. X-Ray lattice measurements are given.

Stable and metastable equilibria in the systems Y_2O_3–Al_2O_3 and Gd_2O_3–Fe_2O_3 I. Warshaw and R. Roy (*J. Am. Ceram. Soc.*, 1959, **42,** Sept., 434–438) The ferromagnetic materials are studied.

Ferromagnetic ceramics: production of some ferrites by solid-state reaction P. V. Olcina Amador, F. C. Landete, and J. I. Fernandez Alonso (*Rev. Ciencia Appl.*, 1959, **13,** March–April, 120–129) A description of work carried out by the authors in the preparation of some simple ferrites, the reactions being examined by thermo-analysis, using the method of continuous weighing. Dissolution of the materials examined is investigated by differential thermal analysis.

Thermal expansion of $MgFe_2O_4$, FeO and $MgO,2FeO$ R. E. Carter (*J. Am. Ceram. Soc.*, 1959, **42,** July, 324–327) Measurements up to 1000°C are reported and discussed.

PROPERTIES AND TESTS

Machines and instruments for material testing (*Draht.*, 1959, **10,** July, 301–305) A description of equipment on view at the German Industrial Exhibition at Hanover in 1959.

Aim and organization of a quality-control department in an iron and steel works and its impact on the works H. Frober (*Stahl Eisen*, 1959, **79,** Oct. 29, 1627–1637) The author outlines the many ways in which a quality-control department could make itself useful to the management of an iron and steel works. He quotes an overwhelming number of examples of items that could be recorded by such a department, these items, when intelligently evaluated and scientifically interpreted, can play an important role in improving the quality of the products.—T.G.

The slope of the bearing area as measure of the surface texture M. Ehrenreich (*Microtecnic*, 1959, **13,** June, 120–125) Due to previous work by the author and a co-worker, which showed that the usual values obtained with a Talysurf, and the profilogram itself did not describe the surface completely, experiments were made and are described which use the bearing area curve due to Abbott and Firestone. The work relates to the reboring of internal combustion engine cylinder blocks.

Surface roughness of hot and cold drawn steel tubes. I. General principles and factors which affect the surface H. Mühlenweg (*Stahl Eisen*, 1959, **79,** Nov. 26, 1792–1795) Condensed from a thesis. A general discussion of surface roughness and defects, their causes and determination, of the effects of working conditions on surface quality and of roughness of the tools on roughness of the tubes and, finally, of the microstructure of the blanks on the working properties and, in turn, on the

surface quality. **II. Factors affecting surface quality during hot working** (1795–1800) The tubes were drawn by the Ehrhardt process which is described in detail. The effect of scaling on subsequent surface quality during the various working operations is discussed. In fact, the scale on the blanks has the greatest influence on the surface quality of the finished tubes, surface quality, in particular cracks in the surface of the tools, has an influence too, but it is very much less. A number of defects caused by the presence of scale are described and illustrated, it is also shown how these defects affect the surface roughness in the various stages of tube-rolling. Scale removal by pressurized water was found to be an excellent remedy.—T.G.

Considerations on the elastic modulus and damping capacity of grey iron E. Plénard (*Centre Technique des Industries de las Fonderie*, 1958, pp.166 + 27 + 41) In the first part, the elastic properties of lamellar graphitic cast iron are studied according to the stress-strain diagram. In the second section, methods used for the measurement of Young's modulus for grey iron are analysed critically; the damping capacity of grey iron is then investigated using a new method, and finally the effects of graphite on the elastic behaviour of grey iron are considered (40 refs).

The mechanics of the plastic deformation of mild steel K. Hohenemser and W. Prager (*Zeitschrift fur angewandte Mathematik und Mechanik*, 1932, **12,** (1), 1–14, trans. *SLA* 59–17712, 1959, pp.17; *RTP trans.* 2468, from *US Dept. Commerce Techn. Trans.*, 1959, **2,** Nov. 20, 740).

The plasticity and failure of quenched steel in a system of plane stresses F. S. Savitskii and O. P. Burmakina (*Fiz. Met. Metallov.*, 1959, (3), 421–425) The deformation curves constructed for quenched steels and low tempered U7 steel in the range of the ratio between the two stresses $\frac{\sigma Z}{\sigma \theta}$ from 0 to infinity depend on the form of the stress system. The onset of the yield point and failure correspond best to the conditions deduced by Yu. I. Yagn (*Vestnik inzhenerov i tekhnikov*, 1931, (6),) and to conditions of plasticity and strength.

Plasticity of transformer steel after heat-treatment between 300–900° S. I. Doroshek (*Fiz. Met. Metallov.*, 1959, (4), 590–594) In the cooling of transformer steel after anneal between 300–900° three falls and two maxima in the viscosity curve are observed. The high temperature fall occurs between 725–825°, the intermediate fall, between 525–725°, and the lower fall between 350–400°. The corresponding maxima are found between 650–700° and 425–450°. The ductility of this steel may be reduced by annealing at the temp. corresponding to the fall in plasticity and improved by annealing at the temp. of maximum plasticity. The plasticity measurements between 300–900° show some complex diffusion processes in microscopic and submicroscopic volumes.

Investigating the workability of hardened steels M. N. Larin and A. A. Maclov (*Vestnik Mashin.*, 1959, (8), 57–61) The article gives the efficient geometrical parameters and processes of cutting for the machining of EKh 12 F steel hardened to 45, 55, and 62–64 RC.

The concentration of the internal friction of deformed alloys on an iron base R. S. Lebedev and V. S. Postnikov (*Fiz. Met. Metallov.*, 1959, (3), 410–417) The maximum internal friction of cold-rolled alloys which are removed after high heat tempering is conditioned by such structural changes which are due to the deformation and the subsequent heating and not by changes in the bonds of the crystal lattice because of alloying. The overall reduction in the level of internal friction on these alloys on an iron base is due on the one hand to an increase in the strength of interatomic bonds and on the other to changes in structure.

The activity of ferrous oxide in silicate melts containing calcium and manganese oxides I. M. Davidson and C. Bodsworth (*JISI*, 1960, **195,** June, 163–169) [This issue].

The distribution of copper, tin, arsenic, antimony, silver and gold between lead melts and carbon-saturated iron melts W. Oelsen, E. Schürmann, and G. Heinrichs (*Arch. Eisenh.*, 1959, **30,** Nov., 649–654) It is shown that Cu removal from iron by scouring with Pb is most satisfactory with C-saturated iron at low temperature. Distribution of Cu between C-saturated iron and Pb and their temperature relations are discussed, the Cu saturation concentration in the Fe phase determined at 1250, 1350, and 1450°C (3·5, 5·8, and 8·2% respectively) and the phase diagram $Fe_{(C)}$–Cu constructed up to 9%Cu. Distribution factors for Sn, As, Sb, and Au were determined. At 1250°, Zn and Sb are removed to the same extent as Cu; Au, and Ag are largely taken up by Pb, while As remains almost entirely in the pig iron (15 refs).

A thermodynamic study of dilute solutions of sulphur in liquid iron, cobalt, and nickel, and binary alloys between these metals C. B. Alcock and L. L. Cheng (*JISI*, 1960, **195,** June, 169–173) [This issue].

The distribution of copper and tin between liquid iron and lead and the influence on it of other metals H. Schenck and W. Spieker (*Arch. Eisenhütt.*, 1959, **30,** Nov., 641–648) The conditions for the removal of Cu and Sn from liquid iron by scouring with Pb are discussed, and experiments described in which equilibrium relationships, the distribution coefficients L_{Cu} and L_{Sn} and their displacement by additional elements, are used to calculate the activity coefficients of the iron binary and more complex solutions. Knowledge of the activity of Cu in liquid iron alloys indicates the extent to which the Cu can be removed by vacuum treatment (20 refs).

Vacancies in metal lattices F. Blaha (*Radex Rund.*, 1959, Dec., 722–733) Point defects are classified with examples, and their origin and movement discussed, and the experimental determination of energies of formation and migration reviewed with reference to the literature. Lack of consistency between results obtained by different methods or based on different theories is discussed (59 refs).

The condition of carbon in iron and steel I. N. Frantsevich, D. F. Kalinovich, and I. I. Kovenskii (*Fiz. Met. Metallov.*, 1959, (4), 574–578) It has been shown that all the carbon atoms in austenite are in the form of positive ions. It is concluded that a similar condition exists in ferrite. It has also been demonstrated that a proportion of iron atoms in austenite are negatively ionized but the degree of ionization falls with an increase in temp. beyond 900°. The mean values of the carbon ionic charges in iron have been calculated. It has also been proved that Hume-Rothery's contention for the existence of covalent bonds in the carbon atoms in austenite, and of the formation of mutually compensating positive and negative carbon ions upon the destruction of these covalent bonds at high temp. is unfounded.

The mechanical properties of low-carbon seamless tubes V. Kravčenko (*Stahl Eisen*, 1959, **79,** Nov. 26, 1801–1803) Tensile and bursting tests on tubes produced from OH and converter steels (killed and not killed) by the Pilger and the Ehrhardt processes showed that yield stress was always higher in the tubes than in the blanks, whereas UTS did not show great changes. Elongation at fracture was affected by the type of steel as well as by the working process. UTS was mostly greater in the longitudinal direction than in the transverse direction, but in one case this was reversed. Bursting strength (tri-axial stress condition) showed the same behaviour as elongation at fracture, it depended on the type of steel and on the working process in a complex manner.—T.G.

Methods normally used in England for establishing the deep-drawing properties of steel sheet J. G. Wistreich (*Mitteilungen der Forschungsgesellschaft Blechverarbeitung e.V.*, 1959, Nov. 1, 293–296) A paper presented at the Annual Meeting of the above association on 26 May, outlining the research work on sheet carried out by the Institute of Sheet Metal Engineering, particularly by the Deep-drawing Group.

Deep drawability of soft boron steels J. Teindl, B. Otta, and M. Velkoborsky (*Sbornik. (Ostrava)*, 1959, **5,** (2), 149–162) [In Czech] Metallurgical and production aspects relating to boron steels are surveyed. Experiments with a steel containing 0·08%C, 0·3%Mn, 0·025%P, and 0·025%S and 0·001 to 0·001 to 0·0045%B showed that boron tended to inhibit ageing, but, in the amounts used, had no significant effect on the Erichsen values obtained; in fact a small deterioration in drawability appeared to have resulted from the addition of boron.—P.F.

The effect of inclusions on the strength of cast carbon steels L. Kuchář and V. Vondrášek (*Sbornik, (Ostrava)*, 1959, **5,** (2), 185–190) The strength and ductility of normalized cast carbon steels containing about 0·23%C were studied in relation to the size and distribution of inclusions. Inclusions of microscopic and smaller dimensions had no observable effects on either mechanical property; larger inclusions affected both adversely. Soviet standard specifications were used for the definition of the inclusion characteristics.—P.F.

The influence of the stress condition on the deformation and strength properties of steels A. Kochendorfer and A. Schürenkämper (*Schweiz. Arch. Wiss. Techn.*, 1959, **25,** Aug., 272–279) The effective polyaxiality of the stress condition in notched specimens at the yield-point can be characterized by a 'polyaxiality number', which is shown by experiments on structural steels to be in general a function of the 'notch number' k. This is discussed in the light of the theories of Hill and Green and of Neuber, and yield-point and breaking stress are measured in a number of normalized and artificially aged structural steels as a function of multiaxiality and temperature. It is shown that susceptibility to brittle fracture and ageing, and notch sensitivity can be determined directly from a three-dimensional representation of this relationship (22 refs).

The mechanical properties of some high-tensile alloy steels I. W. Parsow (*Hutnik*, 1959, **26,** (10), 394–401) In Ni–Cr–W steels, increase in C increases tensile strength but decreases resistance to impact and the same applies to W. Si increases resistance to tempering. Ni can be replaced by Mn without affecting quality.

Influence of tramp elements on the mechanical properties of mild steel N. Eguchi (*Tetsu to Hagane*, 1959, **45,** March, 315–318) The influence of specified ranges of Cu, Sn, As, Ni, and Cr on tensile and other properties for various conditions of the steel are described.—K.E.J.

Surface fissures of hot-worked steel products M. Nakajima (*Tetsu to Hagane*, 1959, **45,** March, 287–289) Surface fissuring of test specimens is related to hot tensile strength at various strain rates; the specimens were vacuum-heated or vacuum-heated and dipped in a copper bath.—K.E.J.

On the plastic bending test. III. General principles applicable to carbon steel K. Sato (*Tetsu to Hagane*, 1959, **45,** March, 313–315).

The high temperature bend-strength of sintered carbides M. Dlouhý (*Hutn. Listy*, 1959, **14,** (8), 692–695) A device for measuring the bend-strength up to 900°C is described, and measurements on carbides used for metal cutting purposes are given. Carbides of the types S1, S2, S3, and S4, which have bend strengths increasing in the order given, at room temperature, all have about the same bend strength at 900°C. The loss in strength amounts to 30–50% in that range, depending upon the carbide quality.—P.F.

On the bendability of heavy steel plates. I. Influence of non-metallic inclusions and banded structure on bendability of heavy steel plates. II. On the relation between bendability and tensile properties, and the laminar defects appearing in bend-broken fractures H. Ishizuka (*Tetsu to Hagane*, 1959, **45,** March, 309–311, 311–313) I. 'Good', 'broken', and 'fissure crack' results in bending tests are correlated with the no., length, and area of sulphide inclusions. Less detailed comparisons are made with pearlitic banded structure. II. The results include a comparison between reduction of area and the type of tensile fracture.—K.E.J.

Evaluation of design and performance of parallel axle gears G. Castellani (*Ing. Mecc.*, 1959, **8,** Oct., 41–48) This article in the series studies methods of determining the stress-resistance of gear teeth. The formula for this is given together with graphs showing the form coefficient for gear teeth for any circle dis-

placement and coefficient tables which enable the real load conditions to be known.

Study on the materials for a steam-turbine generator shaft. Relation between the cooling velocities and the mechanical properties for Cr Mo V steel M. Makioka (*Tetsu to Hagane*, 1959, **45**, March, 360–362) The results include room-temp. mechanical properties, **V**-notch Charpy transition data, and creep and creep-rupture data.—K.E.J.

Determination of residual stresses in cylinders of inhomogeneous material by trepanning and machining E. Krageloh (*Materialprüfung*, 1959, **1**, Dec. 20, 377–384) Equations are derived for the computation of strain into stress for inhomogeneous bodies and for the changes in stress during trepanning or machining of inhomogeneous cylinders. The application of the method is described and examples quoted. A graphical method for the determination of bending moments is also given.—T.G.

Rotary bending fatigue tests on steel 1040 R. M. O. Weinbaum (*Bol. AIBM*, 1959, **15**, Oct., 737–744) This study aims to show that the standard fatigue test does not reveal the change in fatigue resistance in service and that this resistance can be appreciably improved by applying low level stresses before or during the test. Three, non-standard tests were used for this study. The first, applying progressive overstressing, shows that, for an upper limit of overstress, the life of the material is prolonged. The second, using intermittent overstress, shows that the fatigue limit may be improved. Finally damage line testing, to determine the extent of overstressing that can be applied without prejudice to the fatigue limit of the material, is described, and results given.—P.S.

Fatigue tests on joints between pipes and sheets W. Soete and J. Strobelle (*Rev. Soudure*, 1958, **14**, (2), 81–90) The radiographic inspection of welded parts on cranes is discussed. This is followed by a description of fatigue tests carried out on the weld.—R.F.

The fatigue strength of cast iron as a function of its structure and the conditions of application of alternating stresses S. V. Serensen (*Rev. Mét., Mém. Sci.*, 1959, **56**, Dec., 713–720) Investigations on nodular iron of eutectic composition showed that its notch sensitivity was dependent on its structure and increased with decreasing ferrite content. The effect of stress concentrations is a function of the dimensions of the test-piece and of the stress gradients present.

Influence of a non-axial load on the result of fatigue tests under pulsating tensile stresses M. Hempel (*Arch. Eisenh.*, 1959, **30**, Dec., 755–760) The influence of additional flexural stresses on the fatigue strength under pulsating tensile stress of steels was investigated, using flat specimens of St 52 and a 0·9%C unalloyed strip steel. The results were compared with those of microstrain measurements, and the relationship between the additional stresses and fatigue strength discussed.

Fatigue tests on welded joints in motorcycle frames V. Gregor (*Zvar. Shornik*, 1959, **8**, (3), 293–309) [In Slovak] The mode of fatigue fracture was studied in wheel forks of motor scooters and in the frames of motorcycles. Changes in design, which resulted from the tests, and the method of testing are discussed.

Some data regarding vibration strength of low alloy 14G and 19G steels A. A. Bat' (*Avtom. Svarka*, 1959, (5), 91–92) Comparative data were obtained for both these steels by testing double-T welded bearers 12 mm thick. The findings are shown graphically and they indicate that they have nearly the same limits of fatigue.

Fatigue tests on notched specimens the notches of which were filled by welding H. Wolf (*Schweissen Schneiden*, 1960, **12**, Jan., 10–14) Stress concentration at the root of the notches of notched fatigue-test samples is reduced if the notch is filled by welding with a filler metal that has a lower elastic modulus than the basis metal. It was found that arc welding is the best method for filling the notches. An increase of 20–35% in the endurance limit was observed depending on the ratio of the two elastic moduli.—T.G.

On the effect of non-metallic inclusions upon fatigue strength R. Inoue (*Tetsu to Hagane*, 1959, **45**, March, 322–324) Results of mechanical, magnaflux, and microstructure tests are given for medium carbon and Cr–Mo steels.

Fatigue phenomenon of ball bearing steel I. Uchiyama (*Tetsu to Hagane*, 1959, **45**, March, 344–345) The results include the relationship between the stress and the no. of cycles endured, and an analysis of flaking referred to the direction of rolling.—K.E.J.

Effect of the heat treatment on the fatigue strength of crankshafts for a high speed engine S. Yamamoto (*Tetsu to Hagane*, 1959, **45**, March, 349–350) Fatigue results are given for specially shaped test-pieces of JIS S40C, JIS SCM4, and AISI 4340 steels, surface-hardened by high-frequency methods and by nitriding.—K.E.J.

The use of select area electron micrography in studies of the kinetics of fatigue M. Moléik and M. Klesnil (*Hutn. Listy*, 1959, **14**, (8), 688–692) The development of fatigue failure in the early stage of fatiguing was studied in a mild steel. The selected area technique was used on two-stage collodion-carbon replicas.—P.F.

The influence of electrodeposited protective coatings on the fatigue strength of steel H. Tauscher (*Draht*, 1959, **10**, Nov., 571–577) The influence of electrodeposited hard Cr, Zn, and Cd on the mechanical properties in particular the fatigue properties, in a high-strength steel is discussed (40 refs).

Fatigue strength of electro-slag welding joints of O8GDNFL cast steel B. A. Kokh, B. G. Yungel'son, V. A. Bykov, and G. N. Vsevolodov (*Lit. Proizv.*, 1959, (6), 24–26) The strength of electro-slag joints of this steel is equal to that of the base metal. Smooth specimens, on investigation, did not reveal any unfavourable effect on fatigue strength in the absence of thermal treatment after welding.

The influence of the distance between spot welds on long term fatigue limit M. A. El'yasheva (*Svar. Proizv.*, 1959, (3), 22–23) With increasing distance between welding points the limit of fatigue endurance of a spot-welded sheet decreases and the corresponding load on one point increases slightly. As a whole the fatigue strength decreases with an increase between points. The strength coefficient of the welded joint both with cyclic and static loads is greater in proportion as the distance between the points is smaller.

New law relating to fatigue failure of metals V. S. Ivanova (*Doklady AN, SSSR*, (1), 86–89) The basic assumption is that the work of plastic deformation spent in fracturing the specimen, in any desired symmetrical stress cycle exceeding the ultimate fatigue limit is a constant quantity. If Ni is the number of cycles after which submicroscopic cracks appear, the fracture under the given $\pm\sigma$ is expressed by $R\sigma = (N \cdot Ni) = \text{const.}$ where $R\sigma$ is the mean value of the work of plastic deformation for 1 cycle. From a consideration of the physical processes it may be concluded that the difference between the stress causing fatigue failure after a given number of cycles and the stress at which after the same number of cycles, submicroscopic cracks appear, is also constant.

Study of rotating flexural fatigue in various grades of forged and cast structural steels produced at the electric steel plants of ARBED at Dommeldange P. Wagener (*Rec. Tech. Luxembourg*, 1959, **51**, (3), 146–162) A description of the machine used for the tests and preparation of the test pieces is followed by table showing the chemical and physical properties of the steels examined, with individual discussion of the fatigue properties of the alloy steels.

Fatigue tests on parent metals and butt welds A. Kollmar (**Stahlbau*, 1956, **25**, (9), 205–210) A series of tests to replace the 1939–4 results of the VDI welding committee have been carried out. The results suggest that permissible values for the calculation of fatigue stresses should be increased but no recommendations are made as yet.

Fatigue properties of leaded free-cutting steel (*Denki-Seiko*, 1959, **30**, March, 223–224) [In Japanese] A data sheet for S45C, S45CF, SCM22, and SCM22F steels.—K.E.J.

Measurements of damping capacity in the study of fatigue in ferro-magnetic materials K. M. Entwistle (*Rev. Mét.*, 1959, **56**, July, 224–230) Measurements on Ni and several steels, of a peak of magnetic origin in the curve representing the relationship between damping capacity and vibrational strain, showed that the alternating strain for the damping value corresponding to the peak is of the order of magnitude of the mean internal strain of the specimens examined, in accordance with the domain theory. Implications of this result are discussed.

Effect of hydrostatic pressure on the direct-stress fatigue strength of an alloy steel D. J. White, B. Crossland, and J. L. M. Morrison (*J. Mech. Eng. Sci.*, 1959, **1**, June, 39–49) A testing machine was constructed to subject specimens to cyclically varying direct stress with additional tensile and compressive mean stress at atmospheric pressure and at a fluid pressure of ~3000 atm. Results are given.

Relationship between fatigue life of welded pressure vessels and composition of parent metal F. J. Wilkinson and C. L. M. Cottrell (*Weld. Met. Fab.*, 1959, **27**, June, 249–259) The fatigue test results on a number of welded pressure vessels made in 1%Cr–Mo steel are related to the composition of the parent metal. It is shown that S and to a lesser extent P reduce the fatigue life at high stress levels, whereas Ni and C increase the life by promoting better hardenability. When a weld repair is made in high-S material this further reduces the fatigue life.—D.L.C.F.

Some considerations on design for fatigue in welded aircraft structures J. Koziarski (*Weld. J.*, 1959, **38**, June, 565–575) It is recommended that welded joints should work in tension or compression, since shear loading, particularly when longitudinal, gives low fatigue strength. The working of welds by bending should also be avoided. Finally the possibilities of ultrasonic welding are considered.—A.G.

Determination of the creep deflection of a rivet in double shear J. Marin (*J. Appl. Mech.*, 1959, **226**, June, 285–290) The creep of riveted joints is dependant on a number of factors including rivet diameter, rivet length, and plate thicknesses. An approximate theoretical prediction is made of the creep deflection in a rivet based on the creep constants of the material in simple tension.—A.G.

Creep of thick-walled tubes under internal pressure F. P. J. Rimrott (*J. Appl. Mech.*, 1959, **26**, June, 271–275) Using the normal assumptions, equations are derived for the creep rates, strains, and stresses of a thick-walled closed-end hollow cylinder under internal pressure. A known creep rate versus stress relation is then used to solve a specific problem.—A.G.

The creep properties of two molybdenum-bearing austenitic steels H. W. Kirkby (*Alloy Met. Rev.*, 1959, **9**, June, 2–7) Tests on type 316 steels, especially FV555 and FV548 with 0·1% max. C, 16 Cr, and respectively 10·5 and 12%Ni, 2·25 and 1·5%Mo, and in the latter case Nb = 10 × C. A chromium weld deposit was also tested.

Breakage in service of welded structures under stress (*Rivista Ital. Saldatura*, 1959, **11**, March–April, 53–67) This is a critical study of breakage occurring in various types of welded structures. These include a crane, the bulkhead of an oil tanker, the crankshaft of a Diesel engine, the transmission shaft of a rolling mill speed reducer, and the main bridge of a warship.

Lipping in rail heads A. G. Kalashnikov (*Stal'*, 1959, (9), 837–840) Heavily loaded sections of track showed lipping and transverse fatigue fractures. No defects in the metal were found and cold plastic deformation appeared to be the cause. The use of alloy steels and special heat treatment for rails in such locations is advocated.

Combating metal crumbling in the rail cap N. P. Kondakov (*Stal'*, 1959, (9), 840–842) Increased traffic density and speeds have increased wear on rail caps. Better design, especially at curves, and improved metal are suggested to prevent this.

Approximate comparison of hardness scales (*Mat. Design Eng.*, 1959, **50**, Sept., 131) A nomogram connecting Brinell, Moh's scale, and Rockwell B, C, M, and R.

Hardness and brittleness of compounds of metallic character G. V. Samsonov, V. S. Nešpor, and L. M. Chrenova (*Hutn. Listy*, 1959, **14,** (6), 484–489) Microhardness and brittleness of compounds of the transitional elements has been measured. Hardness increases in the order: silicide, nitride, carbide, boride, and brittleness in the order: silicide, boride, nitride, carbide (23 refs).

Determination of yield point by a ball shear hardness test K. Waitzmann (*Materialprüfung*, 1959, **1,** Aug. 2, 261–268) The new non-destructive method for steel examination described is based on shear hardness determination, shear hardness being defined as the stress on the area of the spherical zone resulting from the impression of a ball in a drilled hole. The method is described, evaluated statistically and some applications described.

Some causes of the dispersion of hardness measurements. Comparative study of different indenters A. Meallier and G. Aubrion (*Rev. Mét.*, 1959, **56,** Aug., 327–355) Using mainly a grey iron specimen with a Brinell hardness of about 410, the influence on scatter of various sizes of WC indenters and of a Vickers diamond on the scatter of hardness results was examined; in association with the influence of other factors, such as surface condition and reading error.

Variation in the hardening coefficient related to the development of martensite transformation during plastic deformation M. G. Gaidukov and V. D. Zavodskii (*Metallov. Obra. Met.*, 1958, (5), 4–8) The materials for investigations consisted of a group of austenitic steels and also a carbon-free iron–nickel alloy. The coefficient was measured as ds/d ψ where s is the tensile strength and ψ is the reduction in area. The value of this coefficient is directly related to the difference in stability of austenite in the martensite transformation. Formation of martensite during the deformation process results in an increase in the coefficient.

Variation in hardness measured in relation to the effect of the action of small loads and elasto-plastic hardness F. Giusti (*Ing. Mecc.*, 1959, **8,** Sept., 51–56) The writer asks why the methods of determining hardness are so numerous and varied. He then reviews the various methods in use with a view to establishing the method which gives a definition of hardness for general application.

Study of the hardening and of the loss of hardness of iron alloyed with manganese M. D. Perkas (*Metallov. Obra. Met.*, 1959, (5), 8–13) This study investigates Fe–Mn alloy at deformations between 5 and 90%. For a 3%Mn alloy, 80% deformation increases the tensile strength more than in an iron without Mn. Mn also retards the initial loss of hardness of ferrite in heating. The work-hardening of ferrite is due to the breaking up of blocks.

X-Ray investigation of fatigue in steel at room and low temperatures Yu. S. Terminasov and A. M. Toropov (*Izvest. VUZ Chernaya Met.*, 1959, (7), 75–78) It has been established that 45 steel fatigue at room temp. is accompanied by fragmentation of crystal blocks and that micro-distortion assumes measurable dimensions at the beginning of the process and does not change thereafter. In fatigue in liquid N_2 a considerable increase in micro-distortion and in crystal block fragmentation occurs as compared with room temp.

On the creep-rupture properties of austenitic stainless weld metals T. Suzuki (*Tetsu to Hagane*, 1959, **45,** March 357–358) For AISI 308L 316L and 347 the chemical composition of the weld metal is compared with the creep rupture properties at 650°C.—K.E.J.

Creep properties of 18 8 chromium nickel stainless steel with titanium S. Terai (*Tetsu to Hagane*, 1959, **45,** March, 383–385) Data presented include differences in properties between heats, long-term creep-rupture test results, and the effect of temp. of soln. treatment on creep-rupture strength.—K.E.J.

Investigation of creep in welded joints of heat-resistant steels. Article II. On the failure of the base and weld metals in 15 KHMA and 20 KHMF steels N. L. Kareta (*Avtom. Svarka*, 1959, (8), 41–48) Two types of failures are noticed, intra- and inter-crystalline. Under conditions of long-time service, intercrystalline failure is typical. It is due to viscous slip along grain boundaries and the filling of vacancies in the microcracks so formed.

Investigation of creep in the metal of welded joints of heat-resistant steels. I. Investigation of structural changes in 15 KHMA steel during creep N. L. Kareta (*Avtom. Svarka*, 1959, (6), 3–11) The plastic deformation of creep in this steel was due, under the conditions of the experiment, mainly to simultaneous displacement and polygonization. The sub-boundaries are the shear-planes and also polygonization boundaries. A certain proportion of the plastic deformation is conditioned by viscous slip along grain boundaries. The development of sub-structures in the ferrite grains is accompanied by a hardening of the steel.

On creep rupture strength and ageing hardness. Effect of niobium on austenitic steels Y. Otoguro (*Tetsu to Hagane*, 1959, **45,** March, 371–373) Data are presented for steels having a range of Nb content up to 1·80%, and include the effect of the Nb–C ratio on age-hardness, creep-rupture time, elongation of ruptured specimens at 650°, and high-temp. deformation resistance.—K.E.J.

On the hardness of cast iron Y. Ogiwara (*Tetsu to Hagane*, 1959, **45,** March, 224–226) Data are given for the variation of hardness with distance from the surface or centre, for various heat-treatments of the specimens.

The practical realisation of the HV and HR scales of hardness R. S. Marriner (*Metallurgia*, 1959, **60,** Aug., 63–68) Experiments carried out by NPL using precise indentation hardness testing machines are described; conditions of loading the indentor are varied, and the necessity for precise control of these conditions in standardization work is shown.

Measuring decarburisation by microhardness H. Czyzewski and H. H. Honegger (*Met. Prog.*, 1959, **76,** July, 93) A modification is proposed to the method of using a straightforward microhardness survey to determine depth of decarburization; this gives reduced possibility of error, and the results conform with those from metallographic techniques.—K.E.J.

The ageing of hydrogen-charged rimmed steel H. C. Rogers (*Trans. Met. Soc. AIME*, 1959, **215,** Aug., 666–672) The activation energy for the return of the yield point on ageing has been determined for rimmed steel sheet electrolytically-charged with H_2. The results suggest that H_2 eliminates the yield-point by causing localized plastic deformation.—A.G.

The embrittlement of heat-resisting austenitic steels G. Krüger (*Neue Hütte*, 1959, **4,** Dec., 725–733) Published results on the embrittlement of these steels due to martensite, carbide, and nitride formation, and particularly by ferrite and σ-phase formation were confirmed in the experiments described. It was also shown that carbide formation is a function of time and temperature, and embrittlement by σ-phase is conditioned by time, temperature, and load, and is closely related to the amount of alloy constituents promoting ferrite formation, or to the Cr-equivalent excess.

Investigations of the embrittlement of a heat-resisting austenitic-ferritic chromium–nickel steel H. Schumann (*Neue Hütte*, 1959, **4,** Dec., 733–738) Magnetic and metallographic examination of the X10CrNiWVTa 18·9 steel containing 18%Cr, 10%Ni, and 1–2% of the carbide formers W, V, and Nb+Ta showed that the embrittlement found with short-time annealing at 700–900°C is due to decomposition of δ-ferrite into the hard and brittle σ-phase FeCr.

Prestrain, size and residual stresses in static brittle-fracture initiation C. Mylonas (*Weld. J.*, 1959, **38,** Oct., 414s–424s) Tests are described with the aim of producing consistently in the laboratory true 'brittle' initiations of fracture under central static loading. The effect of prestrain is examined, the mechanisms of fracture initiation is discussed, and the varying influences of residual stresses reviewed. It is concluded that the ductility of sound structural steels is sufficient to prevent appreciable influence of localized residual stresses (37 refs).

Prevention of hydrogen and corrosion embrittlement in high strength steel W. Kloeris jun. (*Ind. Heat.*, 1959, **26,** Aug., 1538) A note covering a discussion at the 11th Western Metal Congress, Los Angeles. Correct cleaning and plating, followed by baking and painting avoids H_2 and corrosion embrittlement in 4340 steel heat-treated to 260000–280000 psi and stressed to 60% of its yield strength.

Reviving the classical theory of friction by a modern dislocation theory of deformation revision J. H. Dismant (*J. Appl. Phys.*, 1960, **31,** Jan., 221–222).

Study of the friction and surface properties of solids F. P. Bowden (*Rev. Mét.*, 1958, **55,** Dec., 1126–1132) The mechanism of solid friction is discussed as well as research into friction of metals and other solids at high sliding speeds. This is followed by a description of reflection and scanning electron microscopy in the study of surface properties. High resolution microscopy is used to show molecular structure of a crystal and to reveal the presence of dislocations.—R.P.

An experimental study on the abrasion of martensitic steel weld metal S. Ito and M. Kawaguchi (*J. Mech. Lab.*, **13,** May, 100–105) The abrasion factors were not so small as those for mild steel for low stress abrasion. The abrasion factors for low-pressure, dry and high-speed abrasions were respectively higher than those for the opposite types. The hardest specimen showed the lowest abrasion factor.

On the reduction of abrasive wear of blades of gas turbines used in the metallurgical industry K. Lobl and J. Vodsed'alek (*Hutn. Listy*, 1959, **14,** (10), 879–885) A detailed study of the influence of welding hard Cr–Ni–W steel edges to Cr–Ni–Ti steel turbine blades was made. Considerable reduction in wear was attained, and fatigue and impact strength of the blades were found to be good. However, the economics of the process are questioned in the discussion of the paper by the referee.—P.F.

The effect of the chemical composition and cooling rate on the resistance to wear of sulphur cast iron N. V. Ivanov (*Lit. Proizv.*, 1959, (4), 35–37) Experience has shown that different rates of cooling and crystallization affect differently the resistance to wear of a sulphur cast iron of constant composition. The tests carried out are given graphically.

Life test of ball-bearing steel E. Miyoshi (*Tetsu to Hagane*, 1959, **45,** March, 345–347) Lifetimes are analysed in relation to Hertz pressure, no. of non-metallic inclusions, and homogeneity.—K.E.J.

Works-designed units solve test problems (in making the FN rifle at R.S.A.F. Enfield) P. Trippe (*Metalw. Prodn.*, 1960, **104,** Feb. 3, 200–203) Devices for optical inspection are described.

Magnetic particle inspection and the most recent methods of indication H. J. Marschall (**Werkstatt und Betrieb*, 1958, **91,** Nov., 649–653) The principle is illustrated and equipment is described with examples of test results.

Magnetic viscosity in carbon steels as a function of fatigue G. Iliescu, D. Barbulescu, G. Savin, and V. Petrescu (*Bull. Inst. Jassy.*, 1958, **4,** (3–4), 259–262) The findings show that the magnetic viscosity is influenced by the degree of fatigue which points to structural changes in the fatigued specimen; the magnetic viscosity increases with the number of cycles as appears from the graphs obtained, that the increases are greater for harder steels, and smaller for ductile steels. The numerical values of magnetic viscosities vary for the same material from specimen to specimen which may be explained by the internal defects of the steels.

On the standardisation of hardenability of steel. III. On the structure and the mechanical properties of standardised Cr Mo steels K. Tsuya (*Nippon Kinzoku*, 1958, **22,** Oct., 497–500) Difference in the ranges of tempered hardness and Charpy impact value as between standardized steels and Japanese Imperial Standards are discussed. A narrow band of hardenability is suggested.—K.E.J.

On the equilibrium state of cracks forming with brittle fracture G. I. Barenblatt (*Doklady AN, SSSR*, 1959, **127,** (1), 47–50) The development of cracks in brittle materials presents the following picture. The material contains a large number of micro-cracks variously oriented. With increasing load at a given point,

tensions are reached sufficient to increase the microcracks to visible dimensions. At first the development of microcracks is determined by definite conditions and since they are generally small as compared with ordinary dimensions, it may be considered that the stress conditions near the cracks, according to Griffiths (*Phil. Trans. Roy. Soc.*, 1920, **221A,** 180), are a uniform tensile stress at infinity. As these cracks increase, their dimensions become related to the changes in stress. In certain conditions, the development of these cracks, on reaching definite dimensions, becomes stationary. The cracks reach an equilibrium condition. This theory is mathematically analysed.

Hydrogen embrittlement of plated steel springs J. A. Gurklis, L. D. McGraw, and C. L. Faust (*PB* 151125, 1956, Dec. 15, pp.43) Except for the decrease in ductility due to H_2 caused by acid or cathodic pickling, it was shown that random variation in the susceptibility of spring steel to H_2 embrittlement was as large as the embrittling effects of cleaning and Cd plating treatments, and hence no heat-treating cycle or other treatments to relieve embrittlement is normally required subsequent to Cd plating. Factors bearing an embrittlement testing are discussed, and recommendations relating to the processing and Cd plating of spring steels to minimize H_2 embrittlement are made.

Crack propagation test of some high-strength sheet steels J. E. Srawley and C. D. Beachem (*NRL Rep.* 5263; *PB* 151352, 1959, Jan. 10, pp.26) Results of crack-propagation tests on eight types of high-strength sheet steels are given as a function of testing temperature, to include the transition from brittle to tough behaviour. Fracture mechanism is discussed for this type of specimen. Results given in an appendix indicate that good agreement is obtained between net fracture-stress values of specimens cracked by H_2 embrittlement and straining, and by fatigue stressing.

Fracture strengths relative to onset and arrest of crack propagation G. R. Irwin, J. A. Kies, and H. L. Smith (*NRL Rept.* 5222; *PB* 151131, 1958, Nov. 20, pp.24) It is indicated that stress conditions controlling extension of a tensile crack can be described by the Griffith theory strain-energy-release rate G. Measurements of critical value G_c for onset of rapid crack extension together with size and location of an actual or assumed starting crack can be made the basis of stress analysis methods of predicting loads required to cause failure by fracture. The relation of section size, temperature and yield stress to G_c is discussed (34 refs).

Symposium on materials research frontiers. New advances in physical metallurgy W. R. Hibbard, jun. (*ASTM*, 1959, *STP* 243, 32–42) A section on brittle fracture and another on cube-oriented Si–Fe alloy are included. (Other contributions are non-ferrous or non-metallic.)

The tendency of superheated steel to reversible temper brittleness as a function of the thermal treatment after second austenitizing B. Rotenstein and N. Dragan (*Studii Cercetari Met.*, 1959, **4,** (3), 127–138) It has been shown experimentally that the brittle tendency of steel quenched from too high a temperature depends on the subsequent heat treatment. A secondary austenitization from a temperature near Chernov's *b* point followed by quenching reduces the transition temperature from fibrous to mixed fractures within the temperature range in which reversible temper brittleness is observed. A secondary quenching from a temperature near Chernov's *b* point reduces the tendency to brittleness irrespective of the tempering heat (500, 600, or 700°C).

The influence of pre-existing sharp cracks on brittle fracture of a nickel molybdenum–vanadium forging steel E. T. Wessel (*ASM preprint* 173, 1959, pp.21) A vacuum-cast steel was highly temperature dependent in the presence of sharp cracks in impact tests and the yield strength shows a sudden transition over a narrow temperature range with a change in mode of fracture. Size effects are important in practical applications as fracture strength varies inversely as the square root of the crack length.

Effect of cold work on temper brittleness A. S. Keh and W. C. Porr (*ASM preprint* 152, 1959, Nov., pp.13) Notch-toughness and tensile tests at ordinary temp. and at −235°F and −320°F were made. Cold work up to 35% before or after embrittling treatment greatly reduced their susceptibility. A difference in solute atom distribution may be the cause.

Correlation between internal friction and temper brittleness in steel A.–F. Kaddou and P. C. Rosenthal (*ASM preprint* 151, 1959, Nov., pp.12) Low alloy and C steels were tested with a torsional pendulum up to 500°F and a new theory of temper-brittleness is advanced. This is based on a dislocation model and suggests anchoring by a Cottrell atmosphere, restricting slip on impact loading. This raises transition temperature and favours intergranular fracture.

The notch toughness of commercial ship plate R. C. A. Thurston (*Can. Min. Met. Bull.*, 1959, **52,** April, 245–254) An investigation carried out on a high-Mn tensile steel in the form of commercial ship plate to assess its suitability for use in the construction of an icebreaker. Results of Charpy V-notch impact tests and tear tests are analyed and compared (13 refs).

The effect of austenitizing, tempering and microstructure on the properties of a Cr–Mo–V steel F. E. Werner, T. W. Eichelberger, and E. K. Hann (*ASM preprint* 172, 1959, pp.20) Factors producing notch-sensitivity in a 1%Cr–1·2%Mo–0·25%V steel were examined. A tempered bainitic structure showed the best mechanical properties, high austenitizing and low tempering temp. produced notch-sensitivity. The steel continues to temper in service above 950°F.

Friction and its measurement F. T. Barnwell (*Met. Rev.*, 1959, **4,** (14), 141–177) A review of the nature of friction, static and rolling friction, and the machines used for measurement (67 refs).

The use of bench wear tests in materials development G. H. Robinson, R. F. Thomson, and F. J. Webbere *SAE Trans.*, 1959, **67,** 569–579) Two accelerated wear tests on engine components used by General Motors and believed to be reliable are described. A constant friction test and a high contact load test are made use of. **Describes wear pattern of chromium on engine cylinder** S. Jacoby (579) A note on the experience of a plating company.

The influence of phosphorus on the wear of machine tool iron castings A. V. Portugeis (*Lit. Proizv.*, 1959, **9,** (2), 38–39) In the light of hardness tests and metallographic investigations, it is concluded that the data point to the necessity of determining accurately the influence of P on the wear properties of cast iron in general and of machine tool castings in particular, as a considerable improvement in quality and a change in the existing standards occur towards higher P contents. It is likewise necessary to re-examine the necessity for limiting the content of ferrite in the structure of machine tool castings. It is apparent that where fine lamellar graphite and disperse fine grain eutectic are produced in the cast iron, it is possible to ensure a sufficiently high level of wear, even where the quantity of ferrite is increased, i.e. at higher C and Si contents.

The present position of photoplasticity E. Mönch (*Schweiss. Arch. Wiss. Techn.*, 1959, **25,** May, 174–180) A review of the literature relating to photo-plastic investigations is given and is divided into two groups, i.e. using models of electroplastic plastics, and the surface layer methods in which a polished metal surface is attached to a layer of photoelastic material (19 refs).

Polarised light tensometry R. V. Baud (*Schweiz. Arch. Wiss. Techn.*, 1959, **25,** May, 155–158) An outline of the development of photoelastic and photoplastic stress measurement, this paper was given as an introduction to a conference on this subject held at Zürich in 1948 (20 refs).

The development of photoelasticity in Britain H. T. Jessop (*Schweiz. Arch. Wiss. Techn.*, 1959, **25,** May, 158–163) The work of Coker and Filon and later workers is outlined, and examples of techniques developed at University College, London, are given (16 refs).

Explanation for the low-temperature behaviour of the anisotropy of iron W. J. Carr jun. (*J. Appl. Phys.*, 1960, **31,** Jan., 69) Magnetic anisotropy is referred to.

Development of cube texture in silicon–iron J. R. Brown (*Iron Steel*, 1959, **32,** Nov., 519–523) The literature of the subject is reviewed, and it is concluded that there are at least three methods of making the material—involving multiple reduction stages, rolling columnar grains, or a method similar to the original Goss process of cold-rolling 3%Si iron. These methods are discussed in the light of present knowledge of texture development in body-centred cubic metals (43 refs).

Magnetic structure of ferro-magnetic substances J. S. Šur (*J. Phys. Radium.*, 1959, **20,** Feb., 113–119) Using a powder pattern technique it has been shown that on single crystals of Si–Fe only certain closure domains can be nuclei of reversed domains and never sub-domains. Other findings on metastable magnetic states are reported.—A.G.

Variation in the saturation magnetization and electrical resistance of iron–nickel alloys under isotropic compression at low temperatures E. I. Kondorskij and V. L. Sedov (*J. Phys. Radium*, 1959, **20,** Feb., 185–191) Measurements in the temperature range 1·7–77°K show that the limiting values of saturation magnetization and resistance as absolute zero is approached depend on the isotropic compression, and, in large applied fields, on the field strength.—A.G.

Relations between grain size and magnetic properties in iron and cobalt amalgams W. Henning and E. Vogt (*J. Phys. Radium*, 1959, **20,** Feb.–March, 277–281) The initial slope of the I=f(T/H) curve is shown to depend only on the total number of particles present. From the temperature dependence of remanence the distribution function of particle size is deduced by the method of Weil and Gruner for a co-amalgam. The implications of these relationships are discussed.—A.B.

Domain patterns and reversals by wall movements of thin films of iron and nickel–iron C. E. Fuller (*J. Phys. Radium.*, 1959, **20,** Feb.–March, 310–318) The reversal of the direction of magnetization by domain wall movements has been studied on thin evaporated ferromagnetic films both parallel and perpendicular to the direction in which a magnetic field was applied during evaporation.—A.G.

Contribution to the study of thin layers of iron and nickel deposited on a copper support at very low temperature R. Conte and L. Weil (*J. Phys. Radium*, 1959, **20,** Feb.–March, 319–322) Some magnetic properties of thin Fe and Ni films deposited at 4·2 and 20°K have been studied. Changes in the coercive force and remanent magnetization on annealing are attributed to structural rearrangement.—A.G.

Some magnetic properties of platinum rich Pt–Fe alloys J. Crangle (*J. Phys. Radium*, 1959, **20,** Feb.–March, 435–437) Measurements of magnetic susceptibility and spontaneous magnetization on face-centred cubic Pt–Fe alloys are reported. In the Pt_3Fe region alloys appear to be antiferromagnetic when ordered and ferromagnetic when disordered.—A.G.

Surface energy of a 90° domain wall in iron: (Erratum) C. D. Graham jun. (*J Appl. Phys.*, 1959, **30,** Dec., 2022; correction to *ibid.* 29, 1451).

Magnetization of the compound TiFe M. V. Nevitt (*J. Appl. Phys.*, 1960, **31,** Jan., 155–157) The range 9–110°K is covered.

Effect of various elements on the properties of non-magnetic steel K. Kusaka (*Tetsu to Hagane*, 1959, **45,** March, 301–303) Results include the effects of varying amounts of carbon and Mn on permeability after heating at 600°C.—K.E.J.

On the mechanical workability of permanent magnet materials Y. Kimura (*Tetsu to Hagane*, 1959, **45,** March, 299–301) Relationships are established between hardness, magnetic properties, and cooling rates for materials such as Vicalloy and Alnico 5.—K.E.J.

Eddy current method for measuring the resistivity of metals C. P. Bean, R. W. DeBlois, and L. B. Nesbitt (*J. Appl. Phys.*, 1959, **30,** Dec., 1976–1980).

Determination of the size of defects by ultrasonics J. Krautkrämer (*Arch. Eisenh.*, 1959, **30,** Nov., 693–703) The difficulties of obtaining

reproducible results by ultrasonic measurements, and in particular obtaining comparable results with different instruments, are discussed, and it is shown that absolute data can be obtained on an echo by using a calibrated amplification regulator, with reference to the first back-echo of a plate.

Ultrasonics—only one of the methods of the material testing of castings R. Schinn (*Giesserei*, 1959, **46**, Dec. 17, 977–980) The ultrasonic testing of high-duty forgings and castings is described, and some examples are given of the testing of castings used in the construction of steam turbines.

Radiographic investigation of dislocations and particle sizes in iron and steel. II. Influence of residual deformations in iron F. Brasse and H. Möller (*Arch. Eisenhütt.*, 1959, **30**, Nov., 685–691) Intensity distribution in Mo–K_α X-ray interference patterns were measured on a mild steel after various degrees of tensile and rolling deformation. In the tensile specimens the changes in lattice constants were determined, and in all specimens the widths at half maximum intensity of the intensity distribution according to inhomogeneous extensions and particle sizes, and the Fourier coefficients of the intensity distributions in reference to the distribution functions of the extensions were evaluated and discussed.

Measurement of lattice constants of stressed specimens with the counter goniometer in the Seemann-Bohlin arrangement A. Segmüller and P. Wincierz (*Arch. Eisenh.*, 1959, **30**, Sept., 577–580) Lattice constants were measured with monochromatic Co–K_α radiation on highly-stressed specimens of Fe–Cu alloys with 2%Cu, quenched from various temperatures after precipitation at 500°C.

Isotope techniques for inspection and evaluation of ship welds E. L. Criscuolo (*Weld. J.*, 1959, **38**, Aug., 324s–328s) Flaw detection and evaluation using radioisotopes are discussed, and the properties of ^{170}Tm, ^{192}Ir, ^{137}Ce, and ^{60}Co are shown and compared.

Excitation functions for (p, n) reactions with titanium, vanadium, chromium, iron and nickel up to Ep=14 MeV S. Tanaka and N. Furukawa (*J. Phys. Soc. Japan*, 1959, **14**, Oct., 1267–1275) Absolute and calculated cross-sections for ^{56}Fe and ^{57}Fe are compared.

Specific heat of high purity iron by a pulse heating method D. C. Wallace, P. H. Sidles, and G. C. Danielson (*J. Appl. Phys.*, 1960, **31**, Jan., 168–176) The range 25–1050°C is covered. Variations near transitions are shown in detail.

Materials for 1200 F/5000 Psi R. J. Fabian (*Mat. Design Eng.*, 1959, **50**, Dec., 87–92) A review of turbine and main piping materials.

The development of heat-resisting and stainless utility steels of the CrMn type for seamless tubes F. Pobořil (*Hutn. Listy*, 1959, **14**, (10), 861–863) MnCr steels alloyed with N, and another austenitic stainless steel Mn–Cr(Ti) 17/7 have been developed to reduce consumption of Ni. The development and properties of the steels are described. They were found to perform well in practice. An MnCrV 17/10 steel was also developed; this performed similarly to the American steels AISI 347 or 348 in creep tests above 550°C.—F.F.

Development of electrical resistance alloys of the FeCrAl type F. Majer (*Hutnik*, 1959, **9**, (9), 289–291) Comparatively short lives of resistance wires containing, apart from iron, 21%Cr and 6%Al, was thought to be due to the S content, the latter being about 0·02%, compared with 0·005% in Kanthal D. However, researches by the author showed that this belief was unfounded; the main cause of the short life being wire heterogeneity due to faulty alloying technology.—F.F.

Solubility and diffusion of titanium in iron S. H. Moll and R. E. Ogilvie (*Trans. Met. Soc. AIME*, 1959, **215**, Aug., 613–618) Incremental multiphase diffusion couples have been used to investigate the solid solubility of Ti in γ-iron and the resulting concentration gradients have been analysed by an X-ray absorption technique. Maximum solubility measured was 0·76% at 1100°C. Interdiffusion coefficients are given for the α- and γ-phases.—A.G.

Investigations of the influence on the equilibrium of nitrogen with liquid iron solutions of the addition of other elements (II) H. Schenck, M. G. Frohberg, and H. Graf (*Arch. Eisenh.*, 1959, **30**, Sept., 533–537) Investigations of the solubility of N_2 in Fe–Ni and Fe–Ni alloys were made at a N_2 pressure of 1 atm. and at 1600°C over the whole range of compositions, and in Fe–C–N, Fe–Mo–N, Fe–S–N, and Fe–Si–N at different partial pressures of N_2. The influence of O_2 on the solubility of N_2 in liquid iron was re-examined, and investigations on the quaternary systems Fe–Cu–Ni–N and Fe–C–Si–N were carried out.

Chemistry in the service of photoelasticity C. Alt (*Schweiz. Arch. Wiss. Techn.*, 1959, **25**, May, 164–168) The structure, and its influence on the mechanical and optical properties of the unsaturated polyester resins used in photoelastic investigations are discussed.

Stress optics in motor construction and related fields A. Kuske (*Schweiz. Arch. Wiss. Techn.*, 1959, **25**, May, 169–173) By means of examples, various methods of investigating strength problems in these fields are examined, including the study of discs and plates by the two shift method, and of spatial problems by means of photoelastic scattering (12 refs).

Grain-oriented steel for laminations (*Sheet Met. Ind.*, 1959, **36**, June, 443–444, 446) An account of the new BTH line.

Direct observation of magnetic domains in cementite M. Hillert and N. Lange (*J. Appl. Phys.*, 1959, **30**, June, 945) The observations are made in polarized light using the Kerr effect.

A simple method of determining the magnetization curve of high-permeability cast steel F. J. Hinsley (*Edgar Allen News*, 1959, **38**, Aug., 173–175; from *BSCRA J.*, 1954, Dec.)

Distribution of magnetic domains between the two phases in a single-crystal flat disc of iron K. F. Niessen (*Philips Res. Rep.*, 1959, **14**, April, 101–110).

The effect of flux distribution on iron losses M. J. Schindler (*WADC Techn. Note* 58–174; *ASTIA Document No. AD* 203785; *PB* 151502, 1958, June, pp.25) Large differences between eddy current losses actually found and those calculated from the classical formula can be attributed partly to the incorrect assumption of constant permeability. Attempts made in this paper to determine approximate solutions for Maxwell's field equation assuming variable permeability suggest however that the assumption of constant permeability accounts for only a small part of the discrepancy obtained.

Investigating structure and magnetic characteristics of the electrolytic depositions of ferromagnetic metals and alloys in relation to the mode of their preparation. I. Nickel Yu. M. Polykarov (*Zhurn. Fiz. Khim.*, 1958, **32**, (5), 1008–1015) The experiments have shown that the coercive force of the electrolytic metal deposits increases with increasing pH of the electrolyte owing to an increase in tensile stresses. A comparison of structure-sensitive magnetic characteristics of Ni obtained by various methods with a proportion of occluded H_2 has proved that the gas is not the source of the internal stresses. The amount of H_2 in the nickel deposits depends on their grain size and on the degree of distortion of the crystal lattice.

The use of colloidal magnetite suspension in the study of the domain structure of ferromagnetics J. Hejduk (*Coll. Czech. Chem. Comm.*, 1959, **24**, Aug., 2792–2794) [In German] The preparation of the colloid is described.

The ΔE effect in iron nickel alloys M. Yamamoto (*Sci. Rep. Res. Inst., Tôhoku Univ.*, 1959, **11**, (2), 102–119) The ΔE effect has been measured by magnetostrictive vibration over the whole range of composition of annealed Fe–Ni alloys. The Young's moduli of α-phase alloys with less than ~20%Ni are not affected by a weak magnetic field, a small negative minimum ΔE effect appears in pure Fe and 60–80%Ni alloys at the field strength where total or differential magnetic susceptibility is a maximum. A secondary increase appears in Fe, Ni, and 80%Ni alloy before saturation, and a slight decrease in 5, 30, and 90%Ni alloys. The results are discussed and the effects of changes in composition on the values of Young's modulus and density are reviewed.

On the methods of determining the specific losses of cold-rolled transformer steel V. V. Druzhinin (*Vestnik Elektropromyshlennosti*, 1959, (5), 41–43) The existing control system for cold-rolled transformer steel of specific losses can result in appreciable differences in results for whole sheets and for narrow strips. Experiments have shown that whole sheets should be tested without retempering, which should be carried out by the users.

The value of tests under a strong magnetic field and their application to the examination of steels P. Bastien and A. Sulmont (*Rev. Mét.*, 1959, **56**, July, 131–143) An apparatus is described by means of which measurements of magnetic intensity can be made between 20 and 700°C on cylindrical specimens, in field strengths ranging from 100–3500 Oe. Rapid and accurate determinations of the magnetic phases in mixed materials such as austenitic-ferritic steels are possible (19 refs).

Investigation of mechanical and magnetic properties of Fe Ni Al alloys for permanent magnets A. A. Shekalov and Ya. I. Shtreis (*Metallov. Obra. Met.*, 1958, (4), 29–38) Alloys of 21 different compositions were studied. Ni improves tensile and impact strengths while aluminium reduces them, copper increases impact strength and reduces the strength in bending and torsion in proportions below 6% but affects the alloy in an opposite manner above this concentration. Sulphur improves mechanical properties and grindability with the optimum effect at 0·2% concentration. For alloys containing cobalt, additions of 0·5–1%Ti and 0·05%Li is recommended.

The control of ferrous bar and tube stock (*SS News*, 1959, June, 21–73) The use of the Magnatest D equipment for the 100% inspection of ferrous bars and tubes for cracks is described.

Single crystal anisotropy and magnetostriction constants of several ferromagnetic materials including alloys of NiFe, SiFe, AlFe, CoNi and CoFe R. C. Hall (*J. Appl. Phys.*, 1959, **30**, June, 816–819).

How fabrication affects stainless magnetic properties W. S. Eberly (*Iron Age*, 1959, **183**, April 23, 106–108) The effects of cold working and annealing on the magnetic properties of ferritic and austenitic stainless steels are discussed. Recommendations are made for obtaining optimum properties for a given application.—A.G.

The industrial uses of ultrasonics J. Palmé (*Techn. Mod.*, 1959, **51**, Sept., 471–476) Direct uses apart from testing methods are reviewed.

Advances in ultrasonic flaw detection J. Brigg (*Control*, 1959, **2**, June, 82–87) An automatic system for production lines is described.

An introduction to ultrasonic testing. III W. E. Schall (*Inspection Eng.*, 1959, **23**, May–June, 49–54) Formulae for energy absorption, and for angle probe skip distance (sheet and tubes) are given.

Determination of the size of defects by the ultrasonic impulse echo method J. Krautkramer (*Brit. J. Appl. Phys.*, 1959, **10**, June, 240–245; *SS News*, 1959, June, 4–15) An attempt is made to develop a universal system for comparison of observations from different kinds of equipment. Using the first back echo from a simple plate an 'equivalent circular disc' can be calculated for the actual defect.

Rapid measurement of the austenite in steel by X-rays E. Minardi (*Met. Ital.*, 1959, **51**, June, 239–240) The method of measuring the austenite in steel by integrating the intensity of the diffraction lines proposed by B. L. Averbach and M. Cohen has been used on a needle-shaped test piece. The results are compared with those obtained using the flat bar method and the conclusion is that with the needle-shaped test-piece a useful analysis can be made with a reduction in the total time needed for analysis of about 10–15 h.

Quantitative deformation textures of aluminium, copper, silver and iron wires A. Freda and B. D. Cullity (*Trans. Met. Soc. AIME*, 1959, **215**, June, 530–535) Skin and inside textures were examined by an X-ray diffractometer method. A single <110> texture was observed for Fe.

High-sensitivity mass spectrometric measurement of stable helium and argon isotopes produced by high-energy protons in iron O. A.

Schaeffer and J. Zähringer (*Phys. Rev.*, 1959, **113,** Jan. 15, 674–678).)

Use of radioisotopes in the foundry L. Soustre (*Rec. Mét.*, 1959, **56,** July, 124–130) Factors influencing the use of gamma radiography for non-destructive testing in the foundry are reviewed. Choice of source, film, screen, and the technique of image production are discussed, and possible lines of development are outlined.

Radioactive cobalt-60, the pill for industrial headaches M. Daly (*Mod. Castings*, 1959, **35,** June, 27–30) A brief outline is given of the underlying principles, techniques, and applications of radiography using ^{60}Co.

Radiation damage in ferrous materials R. E. Smallman (*Iron Steel*, 1959, **32,** May, 175–180; June, 321–322) The effects of neutron irradiation on the mechanical properties of pure iron and ferritic and of austenitic steels are discussed with reference to published results (33 refs). Recovery from radiation damage by annealing, and structure of the damage are then described.

Some experiments on extra low cobalt stainless steels used for nuclear reactors K. Hosoda (*Sumi. Met.*, 1959, **11,** April, 167–169) [In Japanese].—K.E.J.

Heat and corrosion resistant steels (*Aciers Fins. Spéc.*, 1958, Jan., 1–11) The chemical composition, physical, and mechanical properties and thermal treatment of various steels are tabulated. It is emphasized that these tables give only typical figures and are not to be regarded as standard specifications. Special steels are excluded.—R.P.

Ball-bearing steel made with a vacuum induction furnace M. Ueno and H. Makazima (*Tetsu to Hagane*, 1959, **45,** May, 506–510) Gas contents and non-metallic inclusions were small compared with those of air-melted steel. The austenitizing behaviour was the same. Fatigue resistance showed no significant difference, which implies that the content of non-metallic inclusions may not be a main factor in fatigue behaviour.

A selection guide to heat-resistant cast high alloys E. A. Schoefer (*Machine Design*, 1959, **31,** April 2, 118–125) A review of compositions surface and structural stability, mechanical and physical properties and design considerations is given for Fe–Cr–Ni and other alloys.

On recent high-tensile steels. II. M. Yamaki (*Tetsu to Hagane*, 1959, **45,** May, 528–542) A review, dealing with compositions, properties, types of section available, etc. (91 refs).

300-M ultra high strength steel (*International Nickel Co. Inc. Pamphlet*, [1959], pp.12) The composition, properties, and fabrication methods for this steel with 1·85%Ni, 1·6%Si, 0·85%Cr, and 0·75%Mn are given.

Magnitude of the diffusion after-effect as a function of the concentration of iron carbon solid solutions P. Brissonneau (*J. Phys. Radium*, 1959, **20,** Feb., 244–246) The after-effect field has been measured on pure iron samples with varying carbon contents. In accordance with theory, the after-effect is proportional to the concentration of carbon in solid solution, precipitated carbon having no influence.—A.G.

Hydrogen in cold worked iron carbon alloys and the mechanism of hydrogen embrittlement M. L. Hill and E. W. Johnson (*Trans. Met. Soc. AIME*, 1959, **215,** Aug., 717–725) Cold working of iron–carbon alloys was found to increase H_2 solubility and decrease diffusivity at temperatures up to 400°C. Cold working is said to create 'traps' in which H_2 is chemisorbed.—A.G.

Diffusion and penetration of hydrogen into pure iron and steel in the elevated temperature region H. Schenck and H. Taxhet (*Arch. Eisenh.*, 1959, **30,** Nov., 661–671) The experiments described were carried out with a new design of equipment using the permeability method. It was shown that surface reactions can have a strong influence on H_2 penetration through α-iron; activation energy of the complete process equals the sum of those of the partial processes; H_2 permeability is inversely proportional to the fall in concentration of H_2 between the entry and emergence of the gas, and is strongly influenced by temp.; H diffuses in iron in the atomic form; the influence of non-metallic inclusions is very small, and the influence of the lattice structure is greater than those of non-metallic inclusions or alloying additions. Occurrence of defects in the steel can be modified by the inhibiting action in degassing surface reactions of H_2 (24 refs).

On the function of nitrogen as an alloying element in heat-resisting materials. V. Influence of melting atmosphere on the heat-resisting property of 316L steels. VI. The effect of nitrogen content on the nitrogen absorption of 20%Cr Fe alloys. VII. The effect of nitrogen content and carbon content on the nitrogen absorption of 25%Cr Fe alloys R. Tanaka and O. Miyakawa (*Tetsu to Hagane*, 1959, **45,** March, 364–366, 366–369, 369–371).—K.E.J.

Absorption of nitrogen by molten iron. I. Effects of carbon, silicon and manganese on the absorption of nitrogen by molten iron Y. Nakagawa (*Tetsu to Hagane*, 1959, **45,** March, 255–257) Experimental and thermodynamic data are presented for the range 1500–1700°C.

Distribution of silicon between phases in the annealing of magnesium cast iron K. I. Vashchenko, R. P. Todorov, and G. I. Koshovnik (*Lit. Proizv.*, 1959, (4), 20–23) The unequal distribution of Si complicates the processes taking place during the annealing of chilled cast iron. The experiments carried out with Mg iron have confirmed that a prolongation of the first stage of the anneal must not be determined by the time interval necessary for complete graphitization, which, with Mg cast iron is small. To produce good ductile qualities the anneal must ensure not only graphitization but also homogenization of the base metal.

Can nickel-free stainless compete at high temperatures? R. R. Brady and D. T. Boughner (*Iron Age*, 1959, **184,** Aug., 13 90–92) Tests are reported which indicate that a nickel-free stainless steel can compete with the 18-8-type at high temperatures. The steel investigated was Tenelon a high-Mn high-N_2 austenitic steel.—A.G.

New heat resisting steel J. A. Edwards (*Iron Steel*, 1959, **32,** Dec., 576–578) Vascojet 1000 is a medium-C structural steel containing 5%Cr 1·3%Mo, and 0·5%V, said to be very suitable for high strength parts operating between −75 and +540°C with a fatigue and impact properties from 20–35% higher than in other air melted materials, and with a high-temperature strength-to-weight ratio better than that of heat treated Ti alloys. Examples of parts made from the steel are shown, and data on its physical properties and heat treatment are given.

Laboratory of the institute for the working and treatment of steel at Kungl. Tekniska Högskolan in Stockholm G. Wallquist (*Jernkont. Ann.*, 1959, **143,** (11), 701–724) The development of the institute since its formation in 1917 is outlined, and an account is given of the electrical equipment, heat-treating furnaces, experimental rolling and drawing installations and testing facilities. The paper concludes with a list of some of the research work undertaken.

METALLOGRAPHY

The electron microscope in iron and steel research C. G. Nestler (*Technik*, 1959, **14,** Dec., 785–791) The development of electron microscope techniques is reviewed with reference to the literature, and several examples are given, with electron micrographs, of the use of the instrument in iron and steel research (73 refs).

Some new experimental methods in physical metallurgy C. Crussard (*Bull. Cercle Etudes Mét.*, 1958, March, 263–317) The principles, applications, and limitations of modern instruments used by IRSID for the physical examination of metals are discussed in detail. Particular mention is made of X-ray diffraction, micro-calorimetry, micro-analysers, radioactive tracers, radiography, and electron-microscopy. Applications of these techniques to phase determination, phase analysis, segregation and the solidification mechanism of steels are dealt with (17 refs).—R.P.

Separation and analysis of the inclusions in steel M. F. Longinov and N. A. Ermanovich (*Zavods. Lab.*, 1959, (5), 571–473) A method is described which makes it possible without the chemical treatment of anode deposits, to separate the carbide inclusions in steel into the separate phases for the subsequent X-ray and electron diffraction analysis. It consists of a specially constructed vibrator which by means of a magnet first extracts the ferromagnetic phase from the deposits. A mechanical separation of the remainder is then carried out in another special apparatus based on density and sedimentation. Thus this method allows the separation of the anode sediment into fractions, which simplifies the investigation of the phases of the inclusions.

Isolation of non-metallic inclusions in cast steel ingots (sludge method) G. van der Dunk (*Stahl Eisen*, 1960, **80,** Feb. 4, 172–174) An electrolytic method is described for the isolation of non-metallic inclusions in the form of macroscopic slag globules. From the composition, shape, distribution, and quantity their origin and formation can be derived and the necessary steps taken to avoid such inclusions. The approximate composition is SiO_2 28, Al_2O_3 15, FeO 15, MnO + MnS 40% for ingots of rimming mild steel. The amount of slag globules increased with increasing ingot weight and the greatest quantity was always found in the bottom part of the ingot. The diameter of the globules varies between about 0·1 and 1·5 mm.—T.G.

On the distribution of precipitates in corrosion resistant austenitic steels V. Cihal and J. Ježek (*Hutn. Listy*, 1959, **14,** (8), 695–700) Electron micrographic studies of austenitic stainless steels showed that Cr carbides form a discontinuous irregular network on precipitation, mainly near grain boundaries. The morphology of the precipitates did not differ from that of isolated carbide particles.—R.P.

Carbide formation in tempering molybdenum and manganese steels B. A. Apaev (*Izvest. VUZ Chernaya Met.*, 1959, (5), 73–82) This study deals with the formation of carbides in Mo and Mn steels, three iron carbides in Mo steels εFe_xC, χFe_5C, and Fe_3C with Curie points 380, 265, and 210° and the two carbides εFe_xC and Fe_3C in Mn steels.

Use of radioactive isotopes for studying sulphur and non-metallic inclusions in steel production N. S. Mikailets and L. N. Karachentseva (*Chern. Metallurg.*, 1959, (3), 165–169) A summary of the position to date based on publications by Russian workers.

Methods for identification of inclusions in formed steels (*Fonderie*, 1959, Nov., 516–519) A short summary for the identification of sulphide, oxide, silicate, alumina, alumino-silicate, and nitride inclusions in steels is given, using conventional wet methods.—R.P.

Determination of the cerium habit in carbon steel R. H. Singleton (*Trans. Met. Soc. AIME*, 1959, **215,** Aug., 675–679) Vacuum refined carbon steel melts containing specified amounts of S have been exposed to controlled amounts of O_2 and N_2 followed by Ce addition. From metallographic examination and the electrolytic isolation of inclusions it is concluded that the Ce habit is predominantly a cerium sulphide, Ce_2S_3.—A.G.

The recrystallization mechanism of commercial iron after small deformation S. S. Gorelik and G. I. Granik (*Fiz. Met. Metallov.*, 1959, (3), 426–431) The tempering of iron deformed below the critical ratio is accompanied by polygonization, and at the critical ratio by selective recrystallization of the original grains without formation of crystallization nuclei. Deformation beyond the critical ratio is accompanied by a recrystallization both selective and by nuclei formation. The position of the critical point of deformation depends on the rate of heating and changes position with an increase in the rate.

Criterion for peritectic and eutectic reactions Mats Hillert (*JISI*, 1960, **195,** June, 201–204) [This issue].

Regarding the standard methods for determining grain size in steel E. I. Astrov and V. N. Biryukova (*Zavods. Lab.*, 1959, (4), 501–502) According to GOST 5639–51 the size of austenite (inherited) and actual grains are determined either by cementation or oxidation. It has however been shown that in certain cases large differences exist between these two methods. This problem is considered from various aspects.

Effects of heating temperature on the growth of cast iron K. Nagaoka (*Tetsu to Hagane*, 1959, **45**, March, 269–272) Detailed results are presented for the effects of repeated cyclic heating and cooling in various temp. ranges, and the effects of temp. difference on growth in the γ-region.

Hydrogen and nitrogen distribution in steel castings K. T. Kurochkin, B. A. Baum, A. S. Konovalov, V. V. Postyka, and N. F. Timchenko (*Chern. Metallurg.*, 1959, (2), 43–49) During crystallization of the casting, as the front of the growing columnar crystals advances, H_2 separates from the solid metal and enriches the liquid mother liquor. The enrichment of this internal zone during solidification is one of the causes of blister formation, cavities porosities and non-uniformities due to the non-uniform H_2 distribution in the castings. Regarding the distribution of N_2 and its behaviour, one can only say, on the strength of the experimental findings, that it distributes itself unequally.

Phase changes in homogeneous mixed crystal phases W. Köster (*Schweiz. Arch. Wiss. Tech.*, 1959, **25**, Aug., 263–272) An historical survey of the representation of the atomic structure of solid solutions is followed by an account of new work in this field based on measurements of electrical conductivity, the Hall constant and magnetic susceptibility. Most of the cases discussed are non-ferrous but an account of the properties of the Au–Fe system is included (42 refs).

Effects arising from variations in the composition of malleable cast iron on the first stage of graphitization S. Drápal (*Hutn. Listy*, 1959, **14**, (8), 680–688) With carbon contents such as are common in malleable cast irons the time dependence of the isothermal decomposition of ledeburitic cementite was found to depend on the carbon content according to the relation $\%C = K_1 + K_2 \log t$, where K_1 and K_2 are constants. Si accelerates the process most intensively, the shortening of the decomposition time being given by $\%Si = M_1 - M_2 \log t$, with M_1 and M_2 being positive constants. The optimum Mn–S ratio lies between 3 and 4.—P.F.

Contribution to the study of the austenite recrystallization in superheated steel B. Rotenstein and N. Dragan (*Studi. S. Cercet. Met.*, 1959, (3), 295–305) It has been experimentally shown that the austenite recrystallization processes occur also with moderate rates of heating (150–200°/min) for a second austenitizing when the recrystallization occurs between 900–950°C. The recrystallized fine-grained austenite maintains its structure over a wide range of temp. (900–1050°C). A rise in temp. for the first heating from 1200 to 1300°C displaces the interval with fine grain to between 1000–1100°C and a prolongation of keeping for the second heating reduces the recrystallization temp. of superheated austenite.

Physico-chemical investigation of the transformation of the σ-phase in austenitic ferritic molten metal N. Ya. Karasik and N. E. Shlepyanova (*Avtom. Svarka*, 1959, (5), 55–61) X-Ray and chemical analyses are reported on two alloys, one purely austenitic, the other containing 5%ferrite. It was established that the formation of the σ-phase in molten metal is more intensive in the presence of the α-phase. An electrolyte containing 20% aqueous solution HCl, with a small current density (0·02 amp/cm^2) ensures complete solution of the base metal, maintaining the α-phase. The chemical and X-ray analyses have shown that two different transformations occur in the σ-phase of the molten metal according to the ratio Fe:Cr.

The effect of cold-deformation on the γ-σ transformation in welded joints of type 25-20 steel Yu. B. Malevskii and B. I. Medovar (*Avtom. Svarka*, 1959, (7), 40–45) Cold deformation preceding isothermal heating speeds up the formation of the σ-phase in austenitic welded joints. This speeding up of the γ-σ transformation is related to the recrystallization processes. When ageing at relatively low temp. the σ-phase which forms in the new grains appearing during recrystallization, has a pearlitic structure.

Revealing the original structure and intercrystalline liquation in steel and pig irons by austenisation Ya. N. Malinochka and N. G. Osada (*Zavods. Lab.*, 1959, (4), 446–447) The method proposed for revealing macrostructure and intercrystalline liquation in cast steels is by partial austenization. In the crystallization of alloy steels dendritic liquation of alloy elements occurs. If an element which exceeds the A_1 point concentrates between the dendritic axes, then with relatively slow heating the first sections to become austenized will be those poor in the alloy element, i.e. the central (axial) sections of the dendritic branches and the sections where the concentration of the alloy element is greater will not austenize. With intensive cooling the austenite of the dendritic axes transforms into martensite weakly etchable or with martensite plus residual austenite.

Formation of the 'white zone' on the surface of the steel section-shaped wire when drawn, and when working with ropes G. M. Zamoruev, A. L. Tarnavskii, N. S. Vokhomskii, and O. A. Ryabchikova (*Vestnik. Mashin*, 1959, (7), 52–53) The factors promoting the formation of the martensite structure on the surface of Z-shaped drawn strips are numerous and in mass production it is difficult to guarantee their absence. The Magnitogorsk grooving section has produced Z-shaped wires experimentally by drawing through hollow rollers. The wire has high ductile properties and no martensitic structure. The formation of martensitic structure in ropes is also observed in a wide range of components.

Investigation of thermodynamic quantities in the martensitic $\gamma \rightleftharpoons \alpha$ transformation of iron–nickel alloys E. Scheil and W. Normann (*Arch. Eisenh.*, 1959, **30**, Dec., 751–754) Measurements of the heat content between 20 and 900°C of Fe–Ni alloys containing up to 25%Ni were used to derive heats of transformation and to calculate the thermodynamic potentials. It was also shown that transformation temperature is related to pressure by a linear law: $dp/dT = -186$ (kg/cm^2)/°C.

Colour metallography in the study of iron–chromium alloys S. A. Kiseleva and G. A. Faivilevich (*Zavods. Lab.*, 1959, (5), 570–571) Colour metallography is particularly effective to bring out the non-uniformity within the boundaries of single grain or to show up small amounts of one or other phase. This article explains the method of colour etching to study the structure changes occurring during thermal treatment of the binary iron–chromium alloy (39·15%Cr and 0·035%C). The etching is done preferentially with a water solution of $KMnO_4$, 4 g; Na_2O_2, 4 g in 100 ml water at 90° for 2–3 min. Results obtained by this chemical film-etching have made possible a clear separation of the structure of the components and can discover insignificant segregations of the σ-phase.

CORROSION

Electrochemical series of metals in corrosive media encountered in practice J. Elze (*Werks. Korr.*, 1959, **10**, Dec., 737–738) In view of the limited validity of the electrochemical series as a measure of metal corrosion, tests were carried out to obtain a 'practical' series based on corrosion in rainwater and water condensation, and in seawater. In addition to open circuit potential, it was found necessary to know the slope of the current/potential curve in the medium.

Low-temperature boiler corrosion and deposits—a literature review P. D. Moskovits (*Ind. Eng. Chem.*, 1959, **51**, Oct., 1305–1312) (103 refs).

The occurrence and control of low-temperature corrosion caused by flue gases B. J. Alexander (*Chem. Ind.*, 1960, Jan. 9, 28–32) Formation of SO_2 and SO_3 and their determination and effects and the use of inhibitors are described.

Stress corrosion of steel H. Gerbeaux (*Soud. Techn. Connexes*, 1959, **13**, Nov.–Dec., 433–472) Mechanical and physical aspects of stresses and distortions in metals are discussed with special reference to stress corrosion. Characteristics of failures of carbon steel and stainless steel in various corrosive media are considered and related to the conditions of use.—R.P.

Effect of aeration of boiling sulphuric acid on the corrosion-resistance of welded joints of 1Kh18N9T steel N. A. Langer and B. I. Medovar (*Avtom. Svarka*, 1958, (11), 48–51) Thin Cr–Ni austenitic steel corrodes strongly in H_2SO_4. Blowing air through the solution and additions of small amounts of HNO_3 rapidly reduce the rate of corrosion.

Observations on pipes of 2⅜ in. steel APS 10 M4, after 18 months' use in the wells of Lacq 103 E. Herzog (*Corr. Anticorr.*, 1959, **7**, July–Aug., 281–287) Various tests made on several sections of pipe taken up in Sept. 1958: determining loss of weight-examination of corrosion products: chemical composition and constitution of deposits (by X-ray and thermo-magnetic analysis) examination of pipes for concentration of H and mechanical characteristics are reported.—S.H.–S.

Fretting corrosion of metals R. T. Allsop (*Metallurgia*, 1959, **60**, Aug., 39–43) The nature and occurrence of fretting corrosion are examined, the theories of Uhlig, Wright, Waterhouse, and Feng and Rightmire are reviewed and assessed, and the relation between fretting corrosion and fatigue is discussed (22 refs).

Copper, arsenic and antimony in ores, iron and steel. II C. Rekar and R. Brifah (*Rud. Metal. Zbornik*, 1959, (3), 227–258) [In Serbocroat] The detrimental effect of small quantities of these elements in steel is discussed on the basis of a series of experiments. Lower permissible limits are indicated, and the origin of the impurities, and their relation to the ore composition are discussed.—P.F.

Resistance of iron-silicon to various corrosive media (*Aciers Fins. Spéc.*, 1959, **33**, Dec., 91–94) The resistance of alloys containing 0·4–0·8%C and 14–17%Si to various corrosive media under given conditions is summarized in tabular form.—R.P.

Poison tests for the prevention of root penetration into the asphalt/bitumen coating of steel pipes J. F. Bogtstra (*Metaalinstituut TNO. Report No. 66*, 1959, Nov., pp.3) This report emanates from the Committee No.II and describes the investigations conducted with various poisons to combat the penetration of roots into the asphalt/bitumen protective coatings of pipe lines provided with wool felt servings impregnated with various poisonous substances. The pipe lines under test were buried in soils through which the roots of various plants grew. From the results obtained it seems that triethyl tin oxide gives the most promising action followed by that of pentachlorphenol.—F.B.H.

Effect of heating conditions on the descaling of stainless steel A. Sakihama (*Tetsu to Hagane*, 1959, **45**, March, 292–295) Data show the changes in weight on scaling and descaling, the amount of scale recovered and the time for descaling for specimens heated in oxidizing, neutral, and reducing atm., and the same with added SO_3.—K.E.J.

The influence of oxygen pressure on the rate of oxidation of pure iron A. Rahmel and H.-J. Engell (*Arch. Eisenh.*, 1959, **30**, Dec., 743–746) Experiments are described, from which it is shown that O_2 pressure has no detectable influence on the kinetics of oxidation of pure iron at 700, 800, and 950°C, either in pure O_2 at pressures of 100–600 mm, or in a stream of O_2/A mixtures between 7 and 760 mm.

A magnetite seam at the scale/metal interface on mild steel K. Sachs and G. T. F. Jay (*JISI*, 1960, **195**, June, 180–189) [This issue].

Influence of silicon on the high-temperature oxidation of copper and iron J. W. Evans and S. K. Chatterji (*J. Electrochem. Soc.*, 1959, **106**, Oct., 860–866) The effect of 1 at.% Si on pure Fe at 950–1200°C was observed. The effect is considerable and the diffusivity of O_2 in Fe appears to be greater than is generally supposed.

Orientation relation between a hematite precipitate and its ferrite host R. E. Carter, W. L. Roth, and C. A. Julien (*J. Amer. Ceram. Soc.*, 1959, **42**, Nov., 533–536) A Widmanstätten structure was developed by oxidation of a Mn–Zn ferrite and X-ray determination of orientation shows a relationship with only a 3% mismatch between the ferrite and Fe_2O_3.

The displacement of the invariant point between iron, wustite, magnetite and oxygen in

the system iron–oxygen, by means of alloying elements or foreign oxides; effects on the behaviour of iron alloys in scaling E. Brauns, A. Rahmel, and H. Christmann (*Arch. Eisenh.*, 1959, **30,** Sept., 553–564) It is shown from thermodynamic considerations that the limiting temp. of wustite formation, which is 570°C in the Fe–O system, is displaced to higher or lower temp. by the addition of foreign metals or oxides which form solid solutions with wustite, magnetite, and/or iron. These results are confirmed experimentally by oxidizing tests on Fe–Cr, Fe–Ni, and Fe–Mn alloys (32 refs).

The corrosion of iron in aqueous media R. Gomez (*Can. Min. Met. Bull.*, 1959, **52,** Nov., 713–727) Theories and mechanisms are reviewed and notes on painting, coatings and linings, inhibitors and other protective methods are added (21 refs and bibliog. of 19 items).

Observations on the mechanism of attack on aluminium iron–nickel alloys in water vapour below the critical temperature P. Lelong, J. Moisan, and J. Herenguel (*Compt. Rend.*, 1960, **250,** Jan. 11, 340–342) Selective penetration between solid solution and eutectic is demonstrated.

Stainless steels and related alloys versus marine environments J. C. Rowlands (*Corros. Techn.*, **6,** Dec., 359–363) A description is given of a series of corrosion test programmes carried out on a range of stainless martensitic, ferritic, and austenitic steels to determine their behaviour with complete and half-tide immersion in sea water and under aerial conditions. Crevice corrosion due to marine fouling was the main form of attack except in the aerial specimens. The galvanic effect of coupling various stainless steels and related alloys to copper and mild steel was also examined.

Determination of soil corrosion characteristics for the protection of underground installations G. A. Allakhverdiev (*Azerbaydzhanskoye Neftyanoe Khozyaystvo*, 1956, (2), 18–22, translation, from *US Dept. Commerce Tech. Trans.*, 1959, **2,** Oct. 2, 526) Polarization curves in sandy, clay-sand, and argillaceous saline soils on the line of the Baku-Batum pipe-line were traced and used to assess soil corrosivity. Limits within which blisters and penetrating corrosion spots appeared were determined.

Investigations on the influence of air permeability of soils and the corrosiveness of the latter J. W. Boon (*Metaalinstituut. TNO, Report No. 66*, 1959, Nov., 248–251) [In French] The author describes the results of an investigation conducted with soils coming from various parts of Holland to determine the influence of air permeability and their corrosiveness in the presence of cast iron and steel pipe lines. Use was made of recognized test methods for moulding sands suitably modified and also of a new but promising provisional test method developed at the Delft Institute for Metal Research.—F.R.H.

Possibility of transition between stress crack and pitting corrosion in mild steels W. Rädeker (*Arch. Eisenh.*, 1959, **30,** Dec., 747–750) Examination of two examples from practice—a heating tube from a storage tank for alkali and a steel contained in contact with nitrate solution—showed that inter- and intracrystalline stress corrosion can occur at the same time as local, pitting corrosion. It was found in model experiments that in intercrystalline corrosion, grain boundary corrosion predominated with severe tensile stressing, while the local corrosion structure was more in evidence at smaller stresses.

Corrosion tests on enamel finishes F. G. Morriss (*Corros. Techn.*, 1959, **6,** Nov., 346–347) The problem of the resistance of enamels to attack by synthetic detergents, and methods of evaluating this resistance are discussed. The results of tests are considered.

The difference in the chemical attack of corrosion-resistant steels in the welded and not-welded condition H. Zitter (*Berg. hüttenmänn. Monatsh.*, 1959, **104,** Oct.–Nov., 227–228) This is a shortened version of a paper appearing in *Werkstoffe u. Korrosion*, 1959, Oct., 311–321.

Testing the resistance of fluxes to attack by rust E. Stalmašek (*Zváranie*, 1959, **8,** (10), 290–299) Researches on the standardization of tests for the determination of the extent of the liability of fluxes to be attacked by rust, with the consequent pore-formation in the welds, are reported. A simple standard test, free from the variability of existing tests, is described.—P.F.

Tests for corrosion fatigue under bending and torsion L. A. Glikman, E. N. Kostrov, and V. K. Dobrer (*Zavods. Lab.*, 1959, (4), 456–460) The relation between limit of fatigue under torsion τ and under bending σ_{-1} is $\tau_{-1}=\sigma_{-1}\times F$ where F is a factor which varies with the size of the specimen. This relation is, however, not very accurate. A method is proposed which corrects the above relation. It distinguishes materials susceptible to a reduction in fatigue strength with corrosion, independent of hardness and plasticity and corrosion-resistant materials which do not reduce fatigue strength with corrosion. Formulae are derived which give closer results.

Partly-wetted galvanic corrosion couples P. Hersch (*Corros. Techn.*, 1959, **6,** Oct., 293–295) The corrosion of partly immersed metal in conjunction with a number of electrodes was examined, using a bright nickel anode (a) completely submerged, (b) partly immersed in the electrolyte, the anode being completely immersed steel wool.

Study on corrosion of austenitic stainless steel by uranyl salt solution G. Shinoda, T Sano, and T. Kawasaki (*Nippon Kinzoku*, 1958, **22,** Nov., 592–596) Various methods of studying the mechanism of corrosion were evaluated. Nb-stabilized steels showed good corrosion resistance, and their structure and corrosion characteristics were unaffected by neutron irradiation at room temp.—K.E.J.

Study on 17-7 PH stainless steel. II. On the corrosion resistance of such a steel containing 0·7% Al against an aqueous solution of H_2SO_4 and HNO_3 T. Sato and T. Furukawa (*Nippon Kinzoku*, 1958, **22,** Nov., 604–608) In general the corrosion behaviour is similar to that of 18–8 steel. Conditions of cold reduction and ageing to give the best resistance to corrosion by 10% H_2SO_4 are specified.—K.E.J.

Time-temperature-sensitization diagrams for type 347 stainless steel H. F. Ebling and M. A. Scheil (*Met. Prog.*, 1959, **76,** July, 96–B) Temperature-contour and time-contour curves showing corrosion rates, and time-temperature-sensitization curves are given for two heats (analyses given) of type 347 stainless steel. The 'TTS' curves are for mill-annealed sheet, stabilized sheet and sheet cooled after stabilization.—K.E.J.

Corrosion resistance of type 347 stainless after 'sensitizing' heat treatments H. F. Ebling and M. A. Scheil (*Met. Prog.*, 1959, **76,** July, 94–97) Corrosion rates in boiling nitric acid after a series of heatings between 700° and 1500° are plotted as 'TTS (time-temperature-sensitization)' diagrams. These can be used to avoid fabrication practices which would lead to later damage in service.—K.E.J.

The effect of hexamethylenetetramine on the acid corrosion of steels A. S. Afanas'ev, A. P. Brynza, L. E. Gerasyutina, and G. I. Lysenko (*Ukrain. Khim. Zhur.*, 1959, **25,** (1), 73–80) Hexamethylenetetramine as inhibitor of acid corrosion of steel may be considered according to its specific and its neutral actions. An addition of 300 mmol/l of a 0·2N H_2SO_4 raises the pH from 1 to 5. Corrosion losses of steel protected by an oxide film are considerably reduced by additions of hexamethylenetetramine to a 0·2N H_2SO_4 bath. A change in the electrical potentials of three types of steel in the acid, with addition of the base has different signs in the different cases, which explains the coexistence of the specific and neutral effects of this substance.

Modern dew point control system eliminates 'in storage' metal corrosion L. J. Wing Mfg. Co. Ltd (*Ind. Heat.*, 1959, **26,** Aug., 1576–1578) A warm air blower is thermostatically controlled to maintain a temp. differential—usually 15°F—sufficient to prevent condensation, by the use of indoor and outdoor thermometers. The room temp. is restricted to 65° max.; manual control of the system is also provided.

The interest of corrosion research and the protection of metals in the carrying out of large projects G. Chaudron (*Corros. Anticorros.*, 1959, **7,** Feb., 37–45) Corrosion research on metals and corrosion mechanism are reviewed, and the development of anti-corrosive metals and their industrial applications are discussed. Most of the cases cited are non-ferrous.

Corrosion control with cathodic protection W. A. Luce and J. H. Peacock (*Ind. Eng. Chem.*, 1959, **51,** Oct., 57A–58A) An account of the protection of tanks etc. in the chemical and fermentation industries.

Magnesium as an anodic material for the cathodic corrosion protection of seagoing vessels A. Schwarz (*VDIZ*, 1959, **101,** Aug. 1, 1063–1064) A brief outline of the principles and application of the technique, and some data of results obtained.

The effect of tank coating on tanker efficiency International Paints Ltd (*Corros. Tech.*, 1959, **6,** Dec., 369–371) A review of the principal methods of corrosion prevention in cargo tanks is followed by an account of the properties and application of 'Intergard', based on an adduct-cured epoxide system.

ANALYSIS

Contribution to the chemistry of iron and steel: Qualitative rapid tests (1952–57) P. König This is a review of the progress made on rapid tests useful in the iron and steel industry. Not dealt with are spark tests and spectroscopic methods. The tests are arranged alphabetically from Al to Zr and include, as the only non-metal, sulphur (58 refs).—T.G.

Comparative analysis of cast irons M. V. Kuhn and S. Ryser (*Fonderie*, 1959, Nov., 501–515) The authors discuss the methods and approach used in obtaining results from co-operating laboratories. They represent collected results in tabular and graphical form, arriving at a 'probable true result' and issue comments on analyses.—R.P.

Trilonometric determination of iron A. A. Bashkirtseva and E. M. Yakimets (*Zavods. Lab.*, 1959, (5), 540–542) The volumetric determination of iron is described using Trilon in the presence of NH_4 thiocyanate and sulphosalicylic acid. The method is effective for an iron content of from 0·1 to 100 mg Fe^{3+} in 100 ml of sample. The method also allows the determination of ferrous iron in the presence of the ferric by first titrating Fe^{3+} and then, after oxidation, titrating again. In this case the analysis is possible with sulphosalicylic acid alone since thiocyanate needs an oxidizing agent in this titration process.

On the rapid determination of the nitrogen in iron and steel S. Yamazaki (*Tetsu to Hagane*, 1959, **45,** March, 297–299).—K.E.J.

Determination of small amounts of nitrogen in metals and alloys A. I. Ponomarev and A. A. Astanina (*Zhur. Anal. Khim.*, 1959, **14,** (2), 234–238) N_2 is determined by distillation of NH_3, followed by measurement of the pH value of the distillate, made colorimetrically by comparison with a scale of light filters.

Photoelectric analysis of light and heat-resistant alloys and steels K. A. Sukhenko, K. A. Moisseva, L. D. Metelina, I. G. Tishin, N. V. Penkina, and D. G. Bakanov (*Izvest. Akad. Nauk, Seria Fiz.*, 1959, **32,** (9), 1107–1140) A description is given of an attachment to the spectrograph type ISP–22 which can register radiation between 2900 and 2000 Å and a table is given of this analysis of Al and Mg alloys with the appropriate pairs of analytical lines.

The effect of the chemical composition and heat treatment of a steel specimen on the determination of nitrogen by spectral analysis N. V. Buyanov, L. M. Fedorova, and V. F. Korotkov (*Izvest. Akad. Nauk. Seria Fiz.*, 1959, **32,** (9), 1126–1128) The steel specimens were chemically analyzed three times. The spectra were taken in a vacuum chamber containing six specimens and 12 auxiliary electrodes in a vertical position. The gap for the discharge was fixed by a micrometer screw with a possible error of ±0·01 mm. The N spectrum was excited in a chamber first evacuated to 10^{-3} mm and filled with He. Results obtained show that to determine N it is necessary to consider the chemical content of the specimens, their heat treatment and also the purity of the He.

Organic solvents in flame spectrometry A. Puschel and S. Eckhard (*Arch. Eisenh.*, 1959, **30,** Dec., 731–735) The alcohol effect in flame

photometry and its practical application are discussed, with the effect of various factors. The discussion refers to the determination of Fe, Cr, and Mn salts.

Investigating chemical non-uniformity of the zone of the joint with electric contact welding by means of local spectrographic analysis N. V. Bobnitskii and N. A. Grinberg (*Avtom. Svarka*, 1959, (1), 62–69) Two kinds of local spectrographic analysis were used; one of sections of the metal adjoining the region of the joint, and the other for determining the composition of thin layers of metal. The intensification of the oxidation processes with electrical contact welding owing to the existence of the Cr–Mn steel due to an oxide layer on the welding surfaces may cause considerable chemical non-uniformity in the zone of the weld especially as regards Cr and carbon content. The proportion of Mn is hardly affected.

Principles and applications of radioisotopes in the Czechoslovak metallurgical industry R. Jirkovský (*Sbornik (Ostrava)*, 1959, **5,** (3), 263–275) The scope of radioactive isotope applications is surveyed with particular reference to iron and steel production. Equipment of Czechoslovak manufacture, such as thickness gauges, gamma defectoscopes, radiation monitors, remote control manipulators, etc. are discussed.—P.F.

Possibilities of evaluating gas analyses in shaft lime kilns fired with blast furnace gas H. Stempel (*Radex Rund.*, 1959, Dec., 693–697).

Colorimetric determination of alumina in iron- and steelmaking slags with Solochrome Cyanine R P. H. Scholes and Miss D. V. Smith (*JISI*, 1960, **195,** June, 190–195) [This issue].

Study on the chemical analysis of basic slag. II. Determination of FeO, Fe_2O_3, TiO_2, P_2O_5, Cr_2O_3 and S. Determination of FeO, Fe_2O_3 and TiO_2 in basic slag S. Wakamatsu (*Tetsu to Hagane*, 1959, **45,** March, 239–240, Aug., 808–812) A simple method is described. Fe_2O_3 and FeO are determined in the same solution with EDTA. TiO_2 is determined spectrophotometrically using EDTA; at optimum conditions, eight elements do not interfere and four are masked.—K.E.J.

INDUSTRIAL USES AND APPLICATIONS

Metal selector (*Steel*, 1959, **145,** Oct. 26, S1–S32) A survey is presented of 1050 products within 20 categories of ferrous and non-ferrous metals. Compositions, typical applications, and American suppliers are included.—A.G.

Steels for prestressed concrete, their technological properties, selection and testing M. R. Roš (*Schweiz. Arch.*, 1959, **25,** Sept., 338–347) [In French and German] The author summarizes the various methods in use for producing steel for prestressed concrete in the form of rods or wire and lists the factors that affect the technological properties of drawn steel wire. He then discusses the following three problems: which are the steels best suited, by which testing method can this suitability be proved, and how can defective batches of material be eliminated. A comparison—in the form of a table—of the various steel wire standards issued by a number of standard institutes on both sides of the Atlantic is appended (37 refs).—T.G.

The use of coated steel sheets in buildings F. H. Smith (*Sheet Met. Ind.*, 1959, **36,** July, 497–505, discussion 505–510, 536) The applications, advantages, and recent advances in the properties of galvanized, electro-zinc-coated, plastic coated, and painted sheet and strip are discussed. In particular, the fabrication and working possibilities of modern coated steel are emphasized.

Quality requirements of customers for rails W. Grobucki (*Hutnik*, 1959, (9), **26,** 361–364) The author outlines the requirements of purchasers of rails. He gives the specifications rails should meet and says that a National Rail Commission is to be set up.

Progress made in the manufacture of rails S. Struk and J. Ludyga (*Hutnik*, 1959, (9), **26,** 354–360) The authors describe some of the faults in rails manufactured in Poland. In connexion with this, discussion is reported and several experts give their views.

Some examples of the production of files and of the heat treatment of file steel V. Vondrášek (*Sbornik, (Ostrava)*, 1959, **5,** (4), 397–425) A detailed examination is made of the technology and metallurgy of file production. This is illustrated by examples from Czechoslovak practice, and supported by the author's researches on the subject.—P.F.

Application of light-gauge steel sheet and strip in roofing, flooring and sidewall cladding R. J. Shaw (*Sheet Met. Ind.*, 1959, **36,** July, 481–493) The advantages of steel sheet over Al and Cu sheet and non-metallic materials are summarized. The use of steel sheet for roofs, walls, and floors is considered from the design and practical aspects, and the light weight, speed of construction, and electrical and conditioned air availability of a cellular floor construction are particularly stressed.

Vitreous-enamelled steel sheets for curtain walling T. J. Macarthur (*Sheet Met. Ind.*, 1959, **36,** July, 494–496) The manufacture, advantages, and uses of vitreous enamelled steel sheet are considered.

Heat-treated alloy steels in precision roller chains (*Aciers Fins Spéc.*, 1959, **33,** Dec., 44–47) The properties of the various parts of roller chains and their operating characteristics are discussed in relation to composition and heat-treatment of the steels used.—R.P.

A comparison between low-carbon austenitic stainless steels and stabilised steels for welded apparatus in the chemical industry B. Löfblad and G. Lindh (**International Inst. of Welding*, 1958, *Annual Assembly, Vienna*, June, 1958) Comparative investigations are reported between 18/8 austenitic steels and similar steels stabilized with Ti. It is shown that the resistance of austenitic non-stabilized steel with less than 0·06%C to thermal effects in the weld-affected zone is quite as good as that of the Ti-stabilized steels (16 refs).

Production of shielding rings of non-metallic materials for gas pipes N. M. Kolpovskii (*Stal'*, 1959, (10), 937) Polyvinyl chloride has proved best for the protection of the threads of piping.

Use of austenitic steels in the new power station at Hüls A. Engl (**Mitteilungen der vereinigung der Grosskesselbesitzer*, 1958, (55), Aug., 255–264) An account of stress-corrosion and other damage encountered in the steam system, and the grades of steel installed and recommendations made are given.

Rock-joint and sliding shaft linings in cast iron and steel F. Mohr (*Glückauf*, 1960, **96,** Jan. 30, 145–164) The author describes new trends in shaft lining in coal mining and compares the old method—freezing of the soil and use of cast iron sections—with the new one—rolled steel welded to sections *in situ* and concreted rigidly to the rock or sliding on the rock by the use of bitumen. The defects observed in cast iron sections are described in a special chapter.—T.G.

Design, metallurgy and heat treatment of cage and skip suspension gear G. O. Roscoe (*Min. Elect. Mech. Eng.*, 1959, **39,** April, 293–299) Lubrication and inspection are included.

Metallurgical characteristics of stainless steel for boiler tubes T. Yukitoshi (*Tetsu to Hagane*, 1959, **45,** March, 376–377) The properties of 18–8 steels (with and without additions of Nb, Ti, and Mn) and 25–20, 16–13 Mo–Nb, 16–16 Mo–Nb, and 16–16–Mo–Nb–V steels are discussed.—K.E.J.

Metallurgical achievements in evolving heat-resistant steels and alloys for gas turbine construction P. B. Mikhailov-Mikheev (*Teploenergetika*, 1959, (10), 3–8) A review of the new types of steel produced to keep pace with the development of gas turbines and the present position of metallurgy in evolving, among others, pearlitic steels, steels with 12%Cr and austenitic steels and alloys.

High-temperature structural steels for the aircraft industry H. Kiessler (*Stahl Eisen*, 1959, **79,** Nov.26, 1825–1826) This is an extract from the newly published 'Werkstoff-Handbuch der Deutschen Luftfahrt', Berlin, 1959, of a contribution on structural steels by the same author.—T.G.

Carbon steels for wrist-watch springs K. Staňka and O. Modraček (*Hutn. Listy*, 1959, **14,** (8), 674–679) The production technology and testing of 1·2%C watch-springs are surveyed, with special reference to the developments in this field in Czechoslovakia in recent years.—P.F.

Recent investigations on thermo-compensating spiral springs G. Krüger (*Schweiz. Arch. Wiss. Techn.*, 1959, **25,** Aug., 297–307) The magneto-mechanical processes leading to a constant modulus of elasticity with a charging temperature are described, and the additional requirements for spiral springs are reviewed. Ferrous examples discussed are Fe–Ni alloys containing Mo and Be; Cr, Ti, and Be; and Cr, Ti, and Be with increased C content.

Critical discussion and new knowledge on structural steels used for reactors S. Mayerhofer (*Berg. hüttenmänn. Monatsh.*, 1959, **104,** Oct.–Nov., 212–218) The role of structural steels for the construction of reactors is discussed and neutron absorption cross-sections of steels and the induced activity of alloy steels are dealt with in detail. The effect of the various alloying elements on thermal neutron absorption cross-sections and the production possibilities of special steels, such as B-alloyed and low-Co steels are discussed.—T.G.

Steel and steel products for nuclear power plants F. Bruhl and L. Schaeben (*VDIZ*, 1959, **101,** Dec.1, 1645–1649) The effects on steel properties of fast neutron irradiation are reviewed, and the types of steel used for various reactor components are outlined.

HISTORICAL

Bloomery hearth excavations from the forest forge period (11th to 14th Century) in the Märkische Sauerland J. W. Gilles (*Stahl Eisen*, 1960, **80,** Jan.21, 105–106) Historical.—T.G.

St. Leonard: The Iron Saint C. Bohne (*Stahl Eisen*, 1959, **79,** Oct. 29, 1654–1660) Historical. With an account of votive figures, the construction and microstructures being shown.

The quality problem of Swedish iron discussed by N. G. Selfstrom in 1830 R. Arpi and B. Boethius (*Jernkont. Ann.*, 1959, **143,** (5), 277–289).

The Chinese cupola E. A. Sukhodol'skaya and A. M. Petrichenko (*Lit. Proize.*, 1959, (4), 47–48) Cast iron articles were made in China in the VIIIth century B.C. in small cupolas 300–400 mm and 450–700 mm dia. These are described in some detail with some drawings and photographs.

The Russian cupolas at the end of the XVIIIth and beginning of the XIXth century D. M. Modelevich (*Lit. Proize.*, 1959, (4), 42–46) A description of historical interest of these cupolas with some structural details.

A wire centenary (*Wire Ind.*, 1959, **26,** Sept., 859–862) A short account is given of the development of the Halifax wire drawing firm Frederick Smith and Co. from its inception in 1859.—A.G.

ECONOMICS AND STATISTICS

Economic proposition for the production for special grades in a steel plant making mainly tonnage steels H. Peters (*Stahl Eisen*, 1960, **80,** Jan. 7, 28–36) Internal accounting.—T.G.

Development of quantity and price of scrap within the European Common Market for steel and coal W. A. Guldner (*Stahl Eisen*, 1960, **80,** Jan. 21, 90–101) A detailed account of the causes of the scarcity of scrap within the European Common Market and the way this was overcome. The author is confident that there is no danger of a recurrence of such a shortage.—T.G.

Some examples of the application of statistics to the work of a research institute K. Lorenz (*Stahl Eisen*, 1959, **79,** Oct. 29, 1677–1684) Mathematical, mainly treating stress-corrosion data.—T.G.

Advances made in recording and evaluation of operation data and operation results R. Wartmann (*Stahl Eisen*, 1959, **79,** Oct. 29, 1646–1654) The importance of a good internal accounting system is stressed by quoting a number of examples.—T.G.

The presentation of the results of time studies and of transport studies and their evaluation by a punched-card system E. Groger (*Stahl Eisen*, 1960, **80,** Feb. 4, 165–169) The merits of the punched-card system to internal accounting is emphasized and the

adjustments required by this type of system for this particular purpose are discussed.—T.G.

A workable system of establishing time and motion records for economic production also complying with delivery schedules for a jobbing foundry A. Obergetthmann (*Giesserei*, 1960, **47**, Jan. 28, 37–39) A system for internal accounting with the aim of producing the castings in the time allowed by the schedule and at a predetermined price is set out, avoiding the use of too much paper work.—T.G.

Iron and steelmaking in 1965 F. Aranguren Sabas (*Met. Elect.*, 1959, **23**, June, 274–275, 277–279, 281–283) Production of iron and steel and their products in the world is related to probable future developments in capacity and demand, reference being made to the position in Spain.

Contribution to the use of statistical research in the iron and steel industry of the German Democratic Republic H. Spies and W. Naumann (*Technik*, 1959, **14**, Dec., 775–778) The use of statistical methods in quality control is reviewed, and its application to the control of iron and steelmaking processes is outlined.

Frequency studies N. Kjellander (*Jernkont. Ann.*, 1959, **143**, (5), 268–276) The underlying principles and range of application are reviewed.

The U.M.S. system H. E. Biel-Nielsen (*Jernkont. Ann.*, 1959, **143**, (5), 254–267) An account of the Universal Maintenance Standards system, its applications and advantages.

MTM-Method time measurement K. Strömberg (*Jernkont. Ann.*, 1959, **143**, (5), 243–253) An account of the MTM system and its application to work study is given.

Experience with the preparation of accounts at the Nizhne-Tagil' Metallurgical Combine G. P. Zhuravlev (*Stal'*, 1959, (12), 1130–1135) Accounting for individual shops is recommended.

MISCELLANEOUS

Experience in management organization in large integrated plants M. D. Novikov (*Stal'*, 1959, (12), 1126–1129) Integration and reorganization at Nizhne Tagil' is described.

The transport of large quantities of material as an engineering problem in modern iron and steel technology K. H. Huser (*Stahl Eisen*, 1960, **80**, Jan. 7, 1–12) Modern transport ideas and problems and their solutions are discussed and described.—T.G.

How operating with automation affects all company functions G. J. McManus (*Iron Age*, 1959, **184**, Sept. 17, 103–105) The successful application of automation implies constant high volume production of standard parts. The effect of this is discussed in relation to sales policy, part design, and the purchase of raw materials.—A.G.

Production control in an integrated iron and steelworks W. F. Cartwright (*JISI*, 1960, **195**, June, 137–144) [This issue].

Modern ways of organization and methods for increasing the efficiency of trans-shipment plants and transport in the production of steel E. Schmke (*Stahl Eisen*, 1960, **80**, Jan. 7, 12–19) The better utilization and efficiency of transport installations are emphasized, and means for attaining this aim are suggested.

Development and application of a radiation gauge for the analytical evaluation of climatic conditions C. Ploger (*Arch. Eisenh.*, 1959, **30**, Aug., 473–476) The importance of heat radiation in the climatic conditions of an iron and steelworks is pointed out, and an instrument is described by means of which the heat radiated from all directions can be measured simultaneously. A method of assessing the physiological effects of air temperature, wind velocity and heat radiation, and convection is described.

The co-operative workshops technical documentation services A. van Kleef (*Metaalinstituut TNO, Report No.69*, 1959, Dec., 7–8) [In Dutch] The enormous difficulties encountered in keeping abreast of the ever-growing amount of technical literature are pointed out. They have led to the formation of a central body in the Netherlands for dealing with such work. The various organizations pooling their activities in this direction are listed.—F.R.H.

Literature documentation of metallurgical and allied subjects A. H. M. ten Have and K. Verstracte (*Metaalinstituut TNO, Report No.69*, 1959, Dec., 1–6) [In Dutch] The authors summarize and discuss briefly several classification systems dividing them into three main groups, viz. dictionary catalogue, special classifications, and the UDC. The principal abstract journals devoted to the metallurgical field are also mentioned and commented upon.

The accessibility of Russian metallurgical literature A. H. M. ten Have (*Metaalinstituut TNO, Report No.69*, 1959, Dec., 9–10) [In Dutch] The author reviews the different methods making available to the western world Russian technical literature metallurgical in particular. He mentions especially the cover-to-cover translations that are done by various organizations in different countries, the translation services provided by industry to those interested, and the usual translation bureaux.—F.R.H.

On the occurrence of erythema caloricum at pouring work with melted steel, and its prevention S. Maruyama, T. Nakatuo, T. Fujimoto, K. Satoguchi, and K. Yoshida (*J. Labour Hyg.*, 1959, **8**, Aug., 13–21) An improved ingot car protected workers in the pouring of ingots of converter steel.

An experimental study of labour hygiene during converter steel making: Water metabolism and blood constituents in converter steel workers Y. Nambu, H. Muramoto, T. Kasai, Y. Norimatsu, R. Fujioka, M. Kiyonaga, M. Suzuki, K. Ono, M. Nagatomo, and K. Takayanagi (*J. Labour Hyg.*, 1959, **8**, Aug., 30–41). **II. Urine constituents and labour fatigue in converter steel workers** (Nov., 28–36) No special indications of fatigue were observed.

The distribution of sickness absenteeism S. Ogawa, E. Hayashi, and S. Funagoshi (*J. Labour Hyg.*, 1959, **8**, Nov., 37–39) A random sample comprising 459 employees was examined. The distribution of short and long absences is evaluated.

On pneumoconiosis in the iron and steel industry of Japan T. Matsuda (*J. Labour Hyg.*, 1959, **8**, Nov., 7–23).

Use of the Donaggio urine test in industrial fatigue K. Haruda (*J. Labour Hyg.*, 1959, **8**, Aug., 26–29) The expression for mucoprotein per unit volume was superior to the volume per h figure for industrial fatigue studies. More work is needed.

On vitamin excretion of the iron and steel worker. II: The effect of citrate M. Suzuki (*J. Lab. Hygiene*, 1959, **8**, Nov., 24–27) Citrate increases thiamin and ascorbic acid excretion.

Studies on the change of urine components by the use of an organic acid S. Shinjo and T. Kasai (*J. Labour Hyg.*, 1959, **8**, Aug., 22–25) In hot environments four tablets of citric acid 532 mg + sodium citrate 800 mg and one tablet aneurin 2 mg + ascorbic acid 100 mg protected workers from acidosis and reduced fatigue.

Accident prevention by improvement of working conditions taking into account the limits of human efficiency H. G. Haussig and H. Fischer (*Stahl Eisen*, 1959, **79**, Nov. 26, 1810–1813) A number of letters raising some points in Fischer's previous paper (*ibid.*, 1959, 874).—T.G.

Studies on labourers' proneness to accidents in an iron and steel works Y. Kazui (*J. Lab. Hyg. Iron Steel Ind.*, 1959, **8**, Feb., 24–30) A tendency to accidents is associated with latent strabismus, disorders of the motor functions of the legs, poor results in hitting tests, aggresive character, anxiety and indecision. A system of counter-measures is proposed.

Study on possible labour age of employees of a certain iron and steel works. IX. Influences of rationalisation of operation on workers. 2. Rationalisation of charging and transporting raw material for the blast furnace N. Motoda, M. Kiyonaga, and M. Iseri (*J. Lab. Hyg. Iron Steel Ind.*, 1959, **8**, Feb., 18–23) Replacement of manually-handled buckets by an electric car and belt conveyors for transporting iron ore has brought benefits of increased work efficiency, less fatigue, less illness, better attendance, etc. The max. working age of 40 has been considerably extended.—K.E.J.

Studies on labour age in an iron and steel company. VIII. Influence of rationalization on the workers. I. Certain rule-working N. Motoda, M. Kiyonaga, and M. Iseri (*J. Lab. Hyg. Iron Steel Ind.*, 1959, **8**, Feb., 14–18) The conversion of a hot-rolling-mill from 'pull-over' to automatic operation is reflected in improvements in the workers' physical health, as shown by relative metabolic rate, consumption of calories, average age, attendance, incidence of disease, etc. The influences of automation and the reduction of staff on nervous health remain to be investigated.—K.E.J.

Studies on the labour age of an iron and steel works. XIV. Joining age of female workers to the works. XV. Summary and the consideration on labour age and service year distribution of the female workers in an iron and steel works N. Motoda and K. Harada (*J. Lab. Hyg. Iron and Steel Ind.*, 1959, **8**, May, 22–25; 25–28) XIV. Average ages are calculated for various grades of staff, e.g. nurses, office workers, engineers, and general labour. XV. Lengths of service of the different types of female labour are analsyed with respect to types of contact of service, marital status, and physical and mental difficulties of the work.—K.E.J.

Courses for supplementary training of foremen and deputy foremen of the iron and steel industry H. Verhuven (*Stahl Eisen*, 1959, **79**, Nov. 26, 1808–1810) A brief description of courses for foremen of the iron and steel industry lasting four weeks.—T.G.

BOOK NOTICES

AVERBACH, B. L. *et al.* (Editors). '*Fracture*'. Proceedings of an international conference on the atomic mechanisms of fracture, held in Swampscott, Mass. 12–16 April 1959. 9×6 in., pp.xvii+646. Illustrated. New York, London, 1959: The Technology Press of Massachusetts Institute of Technology, Chapman & Hall Ltd. (Price £7.)

Deformation and fracture are the two modes by which materials respond to the application of external force. For the reason of ease of interpretation, perhaps, deformation has attracted the attention of metal physicists for the last twenty years or so, but it can be justifiably argued that fracture, because of its catastrophic nature, is technologically more important. In any case in the field of deformation the dislocation theory can claim a number of successes, but little progress has been made in the field of fracture. The Swampscott Conference has gone a long way towards rectifying this academic injustice. In fact, the proceedings under review are, without doubt, a milestone in the progress of materials technology.

The field covered by the Conference is very wide. Cleavage fracture is the theme of nine papers followed by a group of six papers on fracture phenomena in non-metals. Metal fatigue is discussed in five papers, three deal with ductile fracture and four papers are concerned with fracture at elevated temperatures. Special mention must be made of four outstanding contributions. In the first, A. H. Cottrell considers the theoretical aspects of fracture mechanisms dealt with in the Conference. The other three are summary papers which also outline the needs for future research: C. S. Barrett on cleavage fracture, R. W. Honeycombe on fatigue and ductile fracture, and N. J. Grant on high temperature fracture. The discussion is also recorded following almost all the original contributions.

This is a most valuable volume which can be recommended without hesitation to all those interested in the load carrying capacity of materials. The volume is well produced with a generous number of illustrations and micrographs.—A. H. MELEKA.

DICKMANN, H. '*Aus der Geschichte der deutschen Eisen- und Stahlerzeugung*'. 2. Auflage. Monografien über Stahlverwendung. 9½×8 in., pp.101. Illustrated. 1959, Düsseldorf: Verlag Stahleisen. (Price DM.4.50.)

This interesting booklet, written in a concise and lucid way, describes the historical development of iron and steel manufacture in Germany in its various aspects. The story begins with an iron finger ring of about 150 B.C. discovered in a pagan grave in

north-west Germany, and takes the reader up to the present day. Of particular interest is a diagram (illustration 24, p.36) showing the dimensions of the blast-furnaces in the region of Siegen in Westphalia in 1607. The value of the booklet is greatly increased by 96 illustrations which are very well selected and reproduced.—H. R. SCHUBERT.

DIDEROT, D. '*A Diderot Pictorial Encyclopedia of Trades and Industry*'. Edited by C. C. Gillespie. 2 vols. 12 × 8¼ in. 1959, New York, Dover Publications Inc.; London, Constable & Co. Limited. (Price £7 8*s*.)

In his excellent introduction, Professor Gillespie reminds us of the remarkable conditions in which the 'Encyclopédie, ou Critique Raisonné des Sciences, des Arts et des Métiers' was first produced, and of the struggles of the French Enlightenment against obscurantism.

The plates selected by Professor Gillespie are 485 in number, and cover all the useful arts, including those of war and fashion; of these, 40 on 'Iron Foundry and Forge' cover the metallurgy of iron from mining to cannon founding, with a number on the casting of bronze statues for good measure, and 44 on 'Metal Working' which cover ornamental ironwork, locksmithery, farriery, sword-making, the manufacture of pins, needles, lead pipes, and pewterware, and conclude with a section on coining. Many of these will not be new to readers of technical history; the Encyclopedia, like Swedenborg's 'De Ferro' has long been a valuable source of illustrations of industrial technique. Professor Gillespie and his publishers have done a great service in bringing so many together at so relatively low a price.—J. P. SAVILLE.

DOZINEL, C. M. '*Modern Methods of Analysis of Copper and its Alloys*'. (English translation by G. R. Andraso). 9½ × 6 in., pp.239. 1960, Liège: Ets. Georges Thone. (Price $32.00.)

This is a compilation from the literature of standard methods of determination of copper and the elements usually present in copper alloys, with literature references to the 'less common' constituents (Au, B, Be, C, Co, Hg, Ga, In, S, Ti) though surely Be and S are common enough. The merits of the book, if any, are obscured by the extraordinary 'English' into which it has been translated by George R. Andraso (Pittsburgh). It is in a sort of schoolboy version from the French, not at all Americanized as might be expected, and so obscure in parts that it would be risky to attempt some of the techniques without reference to the originals. The spectrographic and X-ray methods are briefly discussed in a preliminary chapter which is largely a review of apparatus. For a sample, we read 'Rouir et al use a special device to introduce the solutions into the spark. A graphite roller plonging into the solution constantly brings a fresh solution to the spark'. It is reassuring to find later, 'Let us note that a booklet has been published by A.R.L. fully detailing this roller.' Later on we find '*Important precautions*. In the determination of traces, the following should be assured of. *b*. High purity of the reagents. Use bidistilled water (H_2O).' Analysts would obtain little help but much joy from this curious and expensive book.

—J. G. COCKBURN.

EVANS, U. R. '*The Corrosion and Oxidation of Metals: Scientific Principles and practical Applications*'. 9 × 6 in., pp.vi + 1094. Illustrated. 1960, London: Edward Arnold (Publishers) Ltd. (Price £7).

It is doubtful whether any layman could fail to be impressed even by a short glance at Dr U. R. Evans' new book on the corrosion and oxidation of metals. Those who have occasion to undertake or specialize in corrosion studies will greet it as a masterpiece. The production of this book is a remarkable achievement, involving a combination of dogged determination and clarity of thought which perhaps can be fully appreciated only by those who have attempted a similar task. The point may be brought home by the following consideration: in length Dr Evans' book is roughly two-thirds that of H. H. Uhlig's 'Corrosion Handbook', but whereas the latter is the product of an editorial board of ten, including Uhlig himself, and some 100 contributors, Dr Evans has laboured alone.

Length *per se* of course is no great recommendation, but it need hardly be added that the quality is also there. Dr Evans has surveyed, with no detectable omissions, the whole corrosion field, and has given a most erudite and readable account of the subject. The views expressed are his own but they are based on the study of innumerable papers—the Author Index contains about 3000 names—which Dr Evans has interpreted in the light of his own monumental researches. The result is a work that must be of immense benefit to all who are interested in any aspect of the study of the corrosion of metals or who are concerned with practical methods for its prevention. It seems unnecessary to give here a catalogue of the subject matter, since, within the field covered by the title, it is all-embracing. Other writers of scientific books will find much to interest and inspire them in Dr Evans' actual technique. He has, for example, adopted the useful but uncommon course of placing a summary at the beginning of each chapter, and he has given careful consideration to the best way of dealing with references. He has decided to place the latter in the text and the result certainly seems successful. In brief, Dr Evans has surpassed even himself and this, his greatest work, will rank as an outstanding contribution to scientific literature.—J. C. HUDSON.

FEDOT'EV, N. P. and GRILIKHES, S. Ya. '*Electropolishing, Anodizing and Electrolytic Pickling of Metals*'. (Translated by A. Behr from the Russian.) 8½ × 5½ in., pp.x + 285. Illustrated. 1960, Teddington: Robert Draper Ltd. (Price £2 18*s*.)

This book is divided into 11 chapters, one of which covers electrolytic pickling of metals, six cover various aspects of the electropolishing of ferrous, non-ferrous, light and precious metals, and the effect of electropolishing on their properties while the final four deal with the 'anodizing' of aluminium and its alloys, of magnesium, copper and its alloys, zinc, cadmium, steel, and of silver. In this country the word 'anodizing' is not usually used to describe electrolytic processes used to colour copper, steel, and silver surfaces. It is, however, used in connexion with Price & Thomas's process for protecting silver against tarnishing that involves the use of beryllium sulphate and which is acknowledged and described by the authors. From the list of references it is obvious that considerable attention has been devoted to the subject by Russian workers and that the art of electropolishing, anodizing, and electrolytic pickling of metals in Russia and in the western world has reached about the same standard. While the book gives a considerable number of practical details there is little if any justification for the statement on the paper cover that the absence of proprietory interests in Russia makes it possible for authors to discuss the know-how of processes such as hard anodizing, which operators in the west are usually reticent to discuss. Without detracting in any way from the present work it will be appreciated that complete information is available from western sources. The index with which the book concludes is conveniently divided into three separate sections covering anodizing, electrolytic pickling, and electropolishing respectively. The translator, A. Behr, is to be congratulated on the clarity of his translation.—J. F. KAYSER.

FREITAG, K. H. '*Die deutsche Drahtindustrie*'. 8½ × 5½ in., pp.155 + 48 tables. 1959, Düsseldorf: Michael Triltsch Verlag. (Price DM.23.60.)

MCKIE, J. W. '*Tin Cans and Tin Plate*'. 9½ × 6 in., pp.xiii + 321. 1959, Cambridge, Mass., London: Harvard University Press, Oxford University Press. (Price £3.)

These two important books provide outstanding contributions to the study of economic organization. Both authors, particularly the American, make use of modern economic theory and give clear accounts of historical changes in the firm, the industry, and the policy of the State: in doing so they present an interesting comparison in methods of economic analysis.

The German work, which is the broader and more empirical of the two, deals with the development of the German wire-drawing industry, and its market, a theme which, as the author notes, has been the subject of a remarkable number of doctoral theses in that country. The story of competition and combination in the industry is taken from 1817 to the present day and even to the day after tomorrow, for the author concludes with a section on the impact of the Common Market and the European Free Trade Area. The American work is also a study of competition but it is somewhat narrower and different in scope. Instead of one market it deals with two which are related: tin cans and tin plate. It is partly a history of the rise and decline of monopoly in the metal container industry of the United States and of the changing organization and behaviour of the tin plate market. The author shows how prices have been determined and provides a wealth of detail about organization, public policy such as the operation of the Anti-Trust Acts, and the effectiveness of competition at present and its probable development in the future.—M. L. PEARL.

'*Hydraulic Power Transmission*', '*Hydraulic Handbook*', 2nd ed. 9¾ × 7½ in., pp.793. Illustrated. 1960, London: Trade and Technical Press Ltd. (Price £5 10*s*.)

This second edition of a 'handbook' compiled by the editors of '*Hydraulic Power Transmission*', provides a useful if rather expensive compendium of information on the subject. About one-fifth of the book deals with 'Principles', about one-third with a 'Survey of Hydraulic Equipment', and the remainder with 'Applications', 'Technical Data', and a 'Buyers Guide'. In some sections the text is interspersed with a large number of advertisements.

JACKSON, A. '*Steelmaking for Steelmakers*'. 9 × 6 in., pp.xi + 265. Illustrated. 1959, Sheffield: The United Steel Companies (Price £2).

Mr Jackson's book has already appeared in the Iron and Steel Trades Confederation's journal, '*Man and Metal*'; its re-issue will make Mr Jackson's lucid explanations of the open-hearth steelmaking process available to a wider circle of readers. Without in the least 'writing-down', he has produced a book without mathematics or chemical equations, expressed in clear and lively English which is a pleasure to read. Anybody concerned with steelmaking, not only in the melting shop, could study this book with advantage.

—J. P. SAVILLE.

JASTRZEBSKI, Z. D. '*Nature and Properties of Engineering Materials*'. 9 × 6 in., pp.xvii + 571. Illustrated. 1959, New York, London: John Wiley & Sons, Inc.; Chapman & Hall Ltd. (Price £4 8*s*.)

This book is intended for use as a textbook in basic courses in engineering materials but the author has covered so much ground that many sections give a completely false impression of present-day knowledge. A typically confusing section is the one entitled 'Recent Developments in Melting Methods' from which it is improbable that anyone will gather any idea of the way metals are melted. The statement that molten metal is poured from the furnace into a number of smaller containers made of a refractory material and called 'ingot moulds' might lead one to believe that ingot moulds were made from sand or firebrick. The section on permanent magnetic materials is also most misleading. The most widely used permanent magnetic materials are not low-alloy steels, containing from 0·6% to 1·6% carbon, which are hardened by quenching or precipitation hardening. The statement that permanent magnetic materials are usually hard, brittle, and difficult to shape so that they must be cast and finished by grinding is also not correct. Tungsten steel and cobalt magnet steel are still used extensively and can be readily forged and rolled. The statement on page 524 that Calorizing is accomplished by heating a base metal in a mixture

of aluminium oxide and ammonium chloride is also incorrect. Aluminium metal must be present, preferably in the form of fine chips or turnings. Furthermore, the statement that a vapour-phase inhibitor is an inhibitor in vapour form leads one to believe that it is a gas whereas it is a solid. No useful purpose will, however, be served by quoting further examples of the numerous deficiencies of this expensive book.—J. F. KAYSER.

KUTATELADZE, S. S. *et al.* '*Liquid Metal Heat Transfer*'. (Translated from the Russian.) $10\frac{3}{4}\times8\frac{1}{2}$ in., pp.i+149 Illustrated. 1959, New York, London: Consultants Bureau Inc., Chapman & Hall Ltd. (Price £9.)

This is a straightforward thermodynamic development of what has become one of the current topics of chemical engineering, particularly in the field of atomic energy. In its original form it appeared as Supplement No.2 of *Atomnaia Energiia* in 1958. The treatment appears to be conventional, making use of the customary concepts and approximations and discussing the usual ideal cases with extensions to practical applications. The work is packed with experimental data and theoretical and observed curves and tables. A compilation of data on the resistance of materials to attack by liquid metals is given, which should be quite valuable. A final chapter on instrumentation shows much, apparently Soviet, equipment though the origins are not stated. The book deals with fields of heat transfer and heat exchange which are not of much direct interest to the iron and steel industry, more, perhaps, to non-ferrous industries, but the value of data of this kind is not to be underrated and some acquaintance with it is desirable for all workers in the high temperature field.—J. G. COCKBURN.

MANCHESTER JOINT RESEARCH COUNCIL. '*Economic Effects of Fuel and Power in British Industry*'. $8\frac{1}{2}\times5\frac{1}{2}$ in., pp.viii+217. Illustrated. 1960, Manchester: Manchester University Press. (Price £1 5*s*.)

This is a collection of ten papers with discussions presented at a conference organized by the Manchester Joint Research Council on 5–7 November 1958. The treatment throughout is broad and brief dealing mainly with practical questions of a fairly general economic nature. The subjects appear under six main heads: Oil, Coal, Gas, Nuclear Power, Electricity, and (somewhat inconsequentially) 'Future Trends', where a short but interesting paper by Dr T. P. Colclough appears on the metallurgical industry.

SCOTT, F. H. '*The Physical Metallurgy of Rolling*'. $7\times4\frac{1}{2}$ in., pp.vii+94. Illustrated. 1959, Ilfracombe, Devon: Arthur H. Stockwell, Limited. (Price 10*s* 6*d*.)

This book is aimed, it appears, at the 'young apprentice in the trade', who suffers from 'boredom with academic studies'. He should certainly be enlivened by the information that 'X-rays are really light rays with a ripple wavelength about a ten-thousandth that of light', though the gas diffusion equation on page 49, which is clearly exponential, even if no explanation of its symbols is given, may baffle him. He should not worry; it is irrelevant. So, unfortunately is a great deal of this book; homely explanations of the physical behaviour of metals in rolling do not assort well with mathematical formulae, whether these are stated as axioms or lengthily derived. A clear, non-mathematical treatment might have been of use to the apprentice; the mathematical treatment has already been done, as Dr Scott admits by quoting Lee, Nadai, Orowan, Prandtl, and others, elsewhere, and cannot be easily translated into common speech. Moreover, the book is not well written and is badly proof-read; incomplete pairs of brackets, a great dearth of commas, misprints such as 'implicity' and 'scaler', and a remarkably involved grammatical style, have not helped the author to achieve his purpose.—J. P. SAVILLE.

STANFORD, E. G. and FEARON J. H. (Editors). '*Progress in Non-Destructive Testing*'. Vol.2. $9\frac{3}{4}\times6$ in., pp.vii+250. Illustrated. 1960, London: Heywood & Co. Ltd. (Price £2 15*s*.)

This book is the second in a series containing critical reviews on specific aspects of N.D.T., and maintains the high standard set in the first volume. The topics covered include X-radiography, paramagnetic resonance, ultrasonic flaw detection, the application of isotopes, the mechanical properties of high polymers, and the application of electrical methods of testing. As in the previous volume, the emphasis is as much on basic theory as on 'hardware', and the book should be of great interest and value both to the scientist concerned with fundamentals and to the technologist concerned with application. The editors' conception is clearly that non-destructive testing must have a firm basis on physical theory and should not depend on an experimental mystique. The standard of presentation is at the same high level as Vol.1, the text being unfailingly clear and well laid out, with ample diagrams and photographs, and an extensive bibliography to each section.—B. O. SMITH.

STEIBER, J. '*The Steel Industry Wage Structure*'. $9\frac{1}{4}\times6\frac{1}{4}$ in., pp.xi+379. 1959, Cambridge, Mass., London: Harvard University Press, Oxford University Press. (Price £3 4*s*.)

This valuable study of labour relations in the American steel industry deals with the history of job evaluation. The story of the long and complicated negotiations between trade unions and management, which culminated in a historic agreement in 1947, is told with the aid of much new source material. The author, once a research assistant with the United Steelworkers, and now Professor of Economics at Michigan State University, poses a number of problems facing labour and management in the future, among them the adaptation of job evaluation to changing technology and increasing automation.—M. L. PEARL.

TEGART, W. J. MCG. '*The Electrolytic and Chemical Polishing of Metals in Research and Industry*'. 2nd revised ed. $8\frac{1}{2}\times5\frac{1}{2}$ in., pp.x+139. Illustrated. 1959, London, New York: Pergamon Press Ltd. (Price £2.)

This is an excellent book. It is short but clear and concise and very readable, and it is obvious that the author is thoroughly acquainted with the literature and with the practical side of the subject. The book is divided into 11 chapters and concludes with three appendices, a list of 215 references, and an adequate index. The first chapter dealing with The Mechanism of Electrolytic Polishing is particularly clear and it is seldom that one finds so much information in so short a chapter. The Electrical Characteristics of the Polishing Process and Factors Influencing Polishing Conditions are the subject matter of chapters 2 and 3 respectively. Of the remaining eight chapters, four are directed more particularly to laboratory methods and applications and three to industrial applications and methods. For many metals and alloys perchloric acid solutions give a more highly polished and less oxidized surface than any of the other solutions proposed but unfortunately there have been several reports in the technical literature of explosions caused by it and there are still some laboratories who do not allow its use even for research purposes. Chapter 6 will hence be of particular interest to research workers and industrial users as the author deals fully with the explosive properties of solutions used in practice and of the precautions to be taken when using them. Although the book only sets out to be a summary, the author has 'summarized' so effectively that in the majority of cases the particulars of solutions and conditions of working are so concise that it will be quite unnecessary to refer to original sources for further information.—J. F. KAYSER.

TSCHISHIKOW, J. M. [CHIZHIKOV, YA. M.] '*Walzwerkswesen*'. (German transl. from Russian, *Prokatnoe Proizvodstvo*, 1952.) $9\frac{1}{4}\times6\frac{1}{4}$ in., pp.467. Illustrated. 1954, Berlin: VEB Verlag. (Price DM.70.–.)

ZELIKOW, A. I. [TSELIKOV, A. I.] '*Lehrbuch des Walkwerkshaus*'. (German transl. from Russian, *Prokatnye Stany*.) $9\frac{1}{4}\times6\frac{1}{4}$ in., pp.538. Illustrated. 1957, Berlin: VEB Verlag. (Price DM.36.–.)

ZELIKOW, A. I. [TSELIKOV, A. I.] '*Hilfsmaschinender Walzstrassen*'. (German transl. from Russian *Mekhanizmy Prokatnykh Stanov*, 1946.) $9\frac{1}{4}\times6\frac{1}{4}$ in., pp.297. Illustrated. 1954, Berlin: VEB Verlag. (Price DM.58.–.)

FISCHER, E. '*Walzarmaturen*'. $8\times5\frac{3}{4}$ in., pp.170. Illustrated. 1958, Berlin: VEB Verlag Technik. (Price DM.10.–.)

The first three of these books are translated from Russian; according to the preface to the German edition of the first title, this has been done as part of a plan to translate Soviet works dealing with rolling mill practice and related topics. To quote again from the preface, *Walzwerkswesen* is a 'permitted text book' for all USSR technical schools. A very wide field is covered, and inevitably there is some loss of detail; nevertheless, the treatment is thorough within these limits, and the material is logically classified and easy to follow. After an introductory chapter, the principles of plastic deformation are defined and discussed, and relevant laws are stated and illustrated with reference to rolls and roll materials. The next chapter deals with basic rolling theory; in the section on spread the author gives a table showing the influence of steel composition on amount of spread. Plastic properties of metals and alloys are then considered, and the subsequent chapters cover various aspects of the techniques of metal preparation and rolling, from ingot inspection and reheating to the production of sections, tubes, sheet, and strip and so on. Separate sections are devoted to the rolling of alloy steels and non-ferrous metals and alloys, and final chapters review the technology of drawing, and the layout of plant. There are 82 references, mostly from Russian sources, and covering the period up to 1952 (the date of publication of the Russian original). The book is well produced and edited; a minor criticism is the rather poor quality of the paper—a not uncommon fault in technical publications from East German sources.

In *Lehrbuch des Walzwerkshaus*, the range is more restricted, and the treatment correspondingly more exhaustive. The subject matter is divided into five main chapters, both theoretical and practical aspects are considered, and a number of worked examples given. After an introductory section dealing with general aspects of design and construction, expressions are derived for the direction, and location and amount of rolling power and torque (127 pages); next comes a chapter on the individual parts, design and auxiliary equipment of roll stands. Again, a theoretical background is provided, in relation to factors influencing the design of rolls, bearings and housings; the relevant calculations for these, and for the design of screw-down and other mechanisms are given in some detail, and well illustrated with drawings. The next two chapters cover the design of rolling mill drives and their transmission, and special purpose stands (with particular reference to the production of seamless tubes), and the final chapter describes the design of auxiliary equipment—shears, straighteners, coilers, etc. The bibliography of 178 references is classified to correspond with the main subject headings. Arrangement of the text is again good, and the quality of paper is distinctly better than that of the first-named book.

Hilfsmachinen der Walzstrassen, as the title implies, is a still more specialized work. It covers in effect the subject matter of the last main chapter of *Lehrbuch des Walzwerkhaus*, but in much greater detail, and with the emphasis on design calculations. A review of the requirements of drives for auxiliary equipment is followed by a thorough treatment of the design of the equipment itself. Shears, hot saws, straightening machinery, coilers, roller tables, manipulators, and edgers are among the subjects discussed, the treatment in general including calculation of the forces involved and basic design of the equipment. The date of publication of the Russian original was 1946.

Walzarmaturen differs from the other three books in not being a translation. It deals

with the design of guides on the entering side, and of strippers and guides on the delivery side of a large number of types of rolling train, followed by an account of the design of repeaters for various types of mill. The treatment is well-balanced, as foreign designs—mainly American and British—are discussed in addition to German types. Emphasis throughout is on practical aspects of design, and the work is adequately illustrated by sketches and drawings of details and complete parts. In a final section, an account is given of surface defects in the rolled stock attributable to this equipment. The book can be recommended as an addition to the library of rolling mill engineers.

—L. D. HEWITT.

NEW PUBLICATIONS

These titles are also available on index cards in advance of publication in the Journal, *each title being classified under the Universal Decimal system (UDC). Details and subscription rates can be obtained from the Secretary, The Iron and Steel Institute.*

AMERICAN SOCIETY FOR TESTING MATERIALS. '*Symposium on Microscopy*'. STP No.257. 9×6 in., pp.165. Illustrated. Philadelphia, 1959: The Society. (Price, Non-members $4.75, Members, $3.80.)

AUGUST THYSSEN-HÜTTE, AG. MICHEL, A. *et al.* '*Technische und wissenschaftliche Berichte der August Thyssen-Hütte*'. Band 1. [25 papers, mainly re-printed.] 11½×8¼ in., pp.237. Illustrated. Duisburg-Hamborn, 1959: August Thyssen-Hütte AG.

BRITISH CHEMICAL PLANT MANUFACTURERS ASSOCIATION. '*British Chemical Plant*'. 1959 Edition. 11×8½ in., pp.450. Illustrated. London, 1960: The Association.

BRITISH IRON AND STEEL FEDERATION. '*British Standards for Steel. Summary Sheets. Metric units. Section 3. Steel for Railway purposes*'. Compiled in collaboration with the British Standards Institution. [Container holding Metric editions of]: Sheet 3a, Flat Bottom Railway Rails and Steel Sleepers for Flat Bottom Railway Rails, PD 3289; Sheet 3B, Axles, Tyres, Solid Rolled Steel Wheels and Disc Wheel Centres for Railway Rolling Stock, PD 3255; Sheet 3c, Steel Billets, Blooms, Bars and Forgings for Railway Stock, PD 3275; Sheet 3D, Steel Slabs, Plates, Sections, Bars and Rivets for Locomotive Boilers, Locomotives, Carriages and Wagons, PD 3381; Sheet 3E, Laminated Springs and Spring Steels, PD 3340; Sheet 3F, Helical and Volute Springs and Spring Steels, PD 3393. 23×16½ in. (folded, 6×8 in) Illustrated. London, 1960: The Federation.

BRITISH IRON AND STEEL FEDERATION. '*Britische Normen für Stahl. Auszugs-Blätter. Abschnitt 3. Stahl für Eisenbahnbedorf*'. Zusammengestellt in Zusammenarbeit mit der British Standards Institution. [Container holding Metric editions and German translations of]: Sheet 3A (PD 3372); Sheet 3B (PD 3288); Sheet 3C (PD 3370); Sheet 3D (PD 3481); Sheet 3E (PD 3444); Sheet 3F (PD 3397). 23×16½ in. (folded, 6×8 in.) Illustrated. London, 1959: The Federation.

BRITISH IRON AND STEEL FEDERATION. '*Normas Británicas Para el Acero. Hojas Resumen. Sección 3. Acero para Ferrocarriles*'. Compiladas en Colaboración con la British Standards Institution. [Container holding Metric editions and Spanish Translations of]: Sheet 3A (PD 3445); Sheet 3B (PD 3388); Sheet 3C (PD 3389); Sheet 3D (PD 3418); Sheet 3E (PD 3443); Sheet 3F (PD 3407). 23×16½ in. (folded, 6×8 in.) Illustrated. London, 1959: The Federation.

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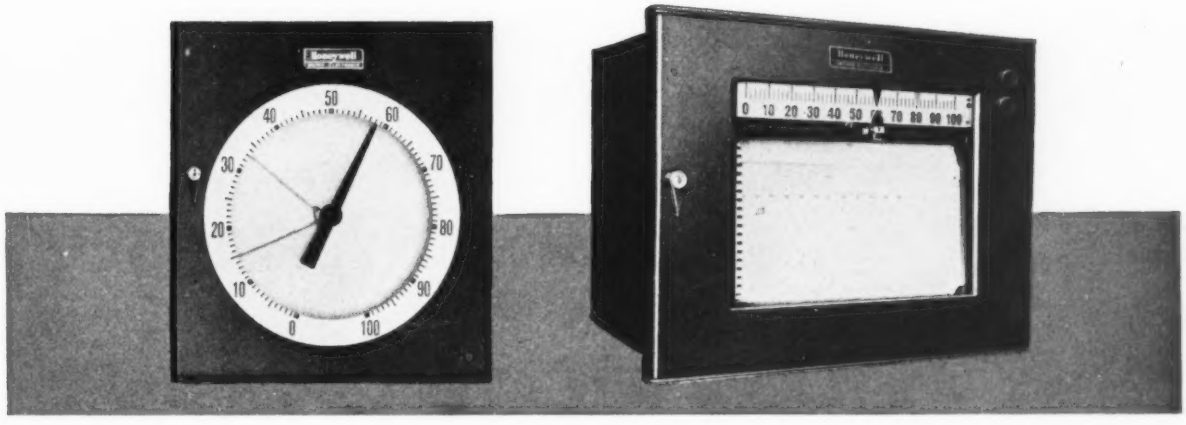

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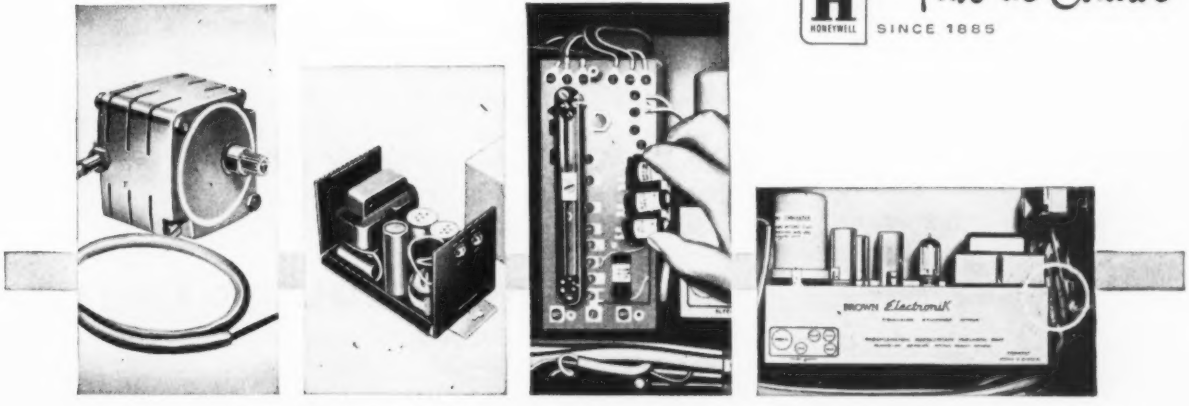

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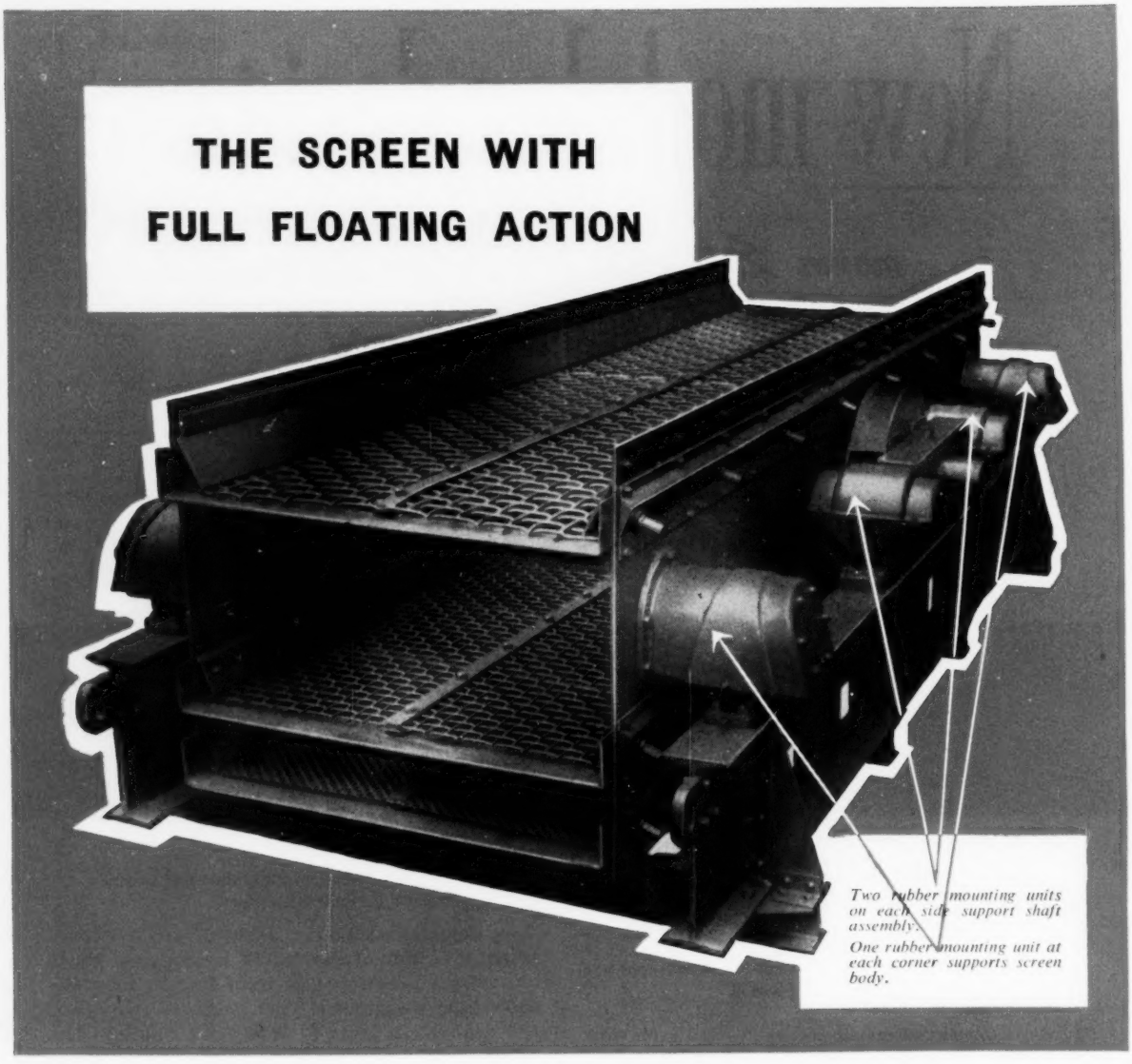
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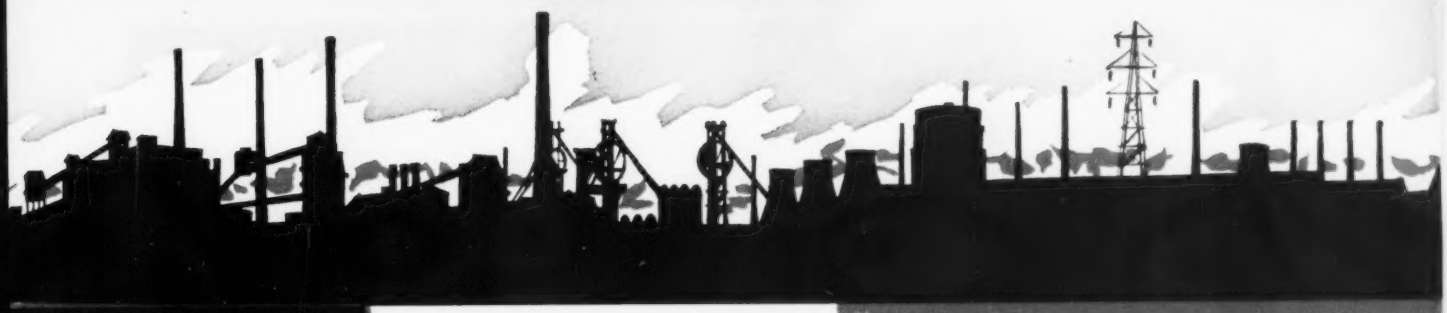

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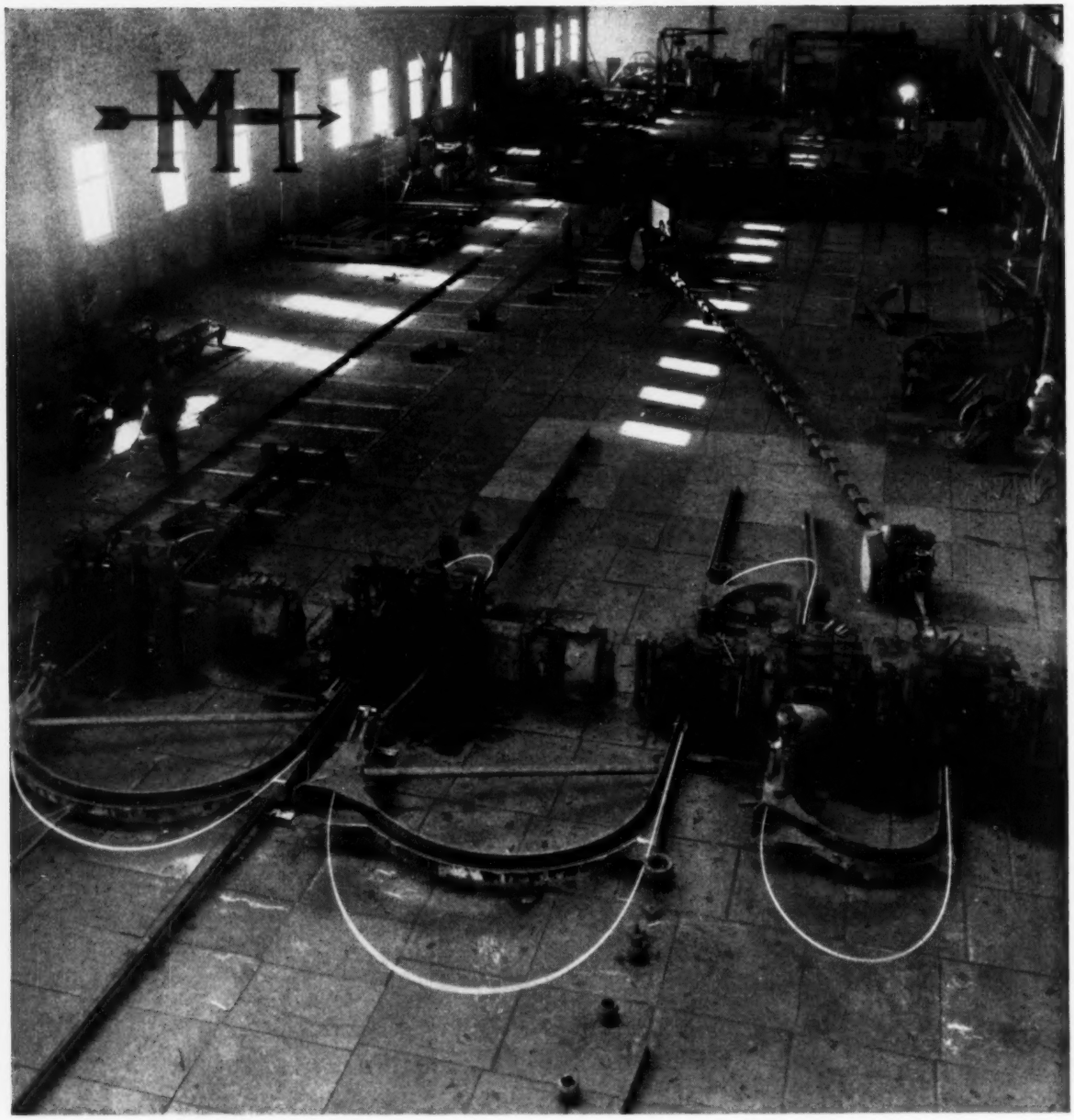

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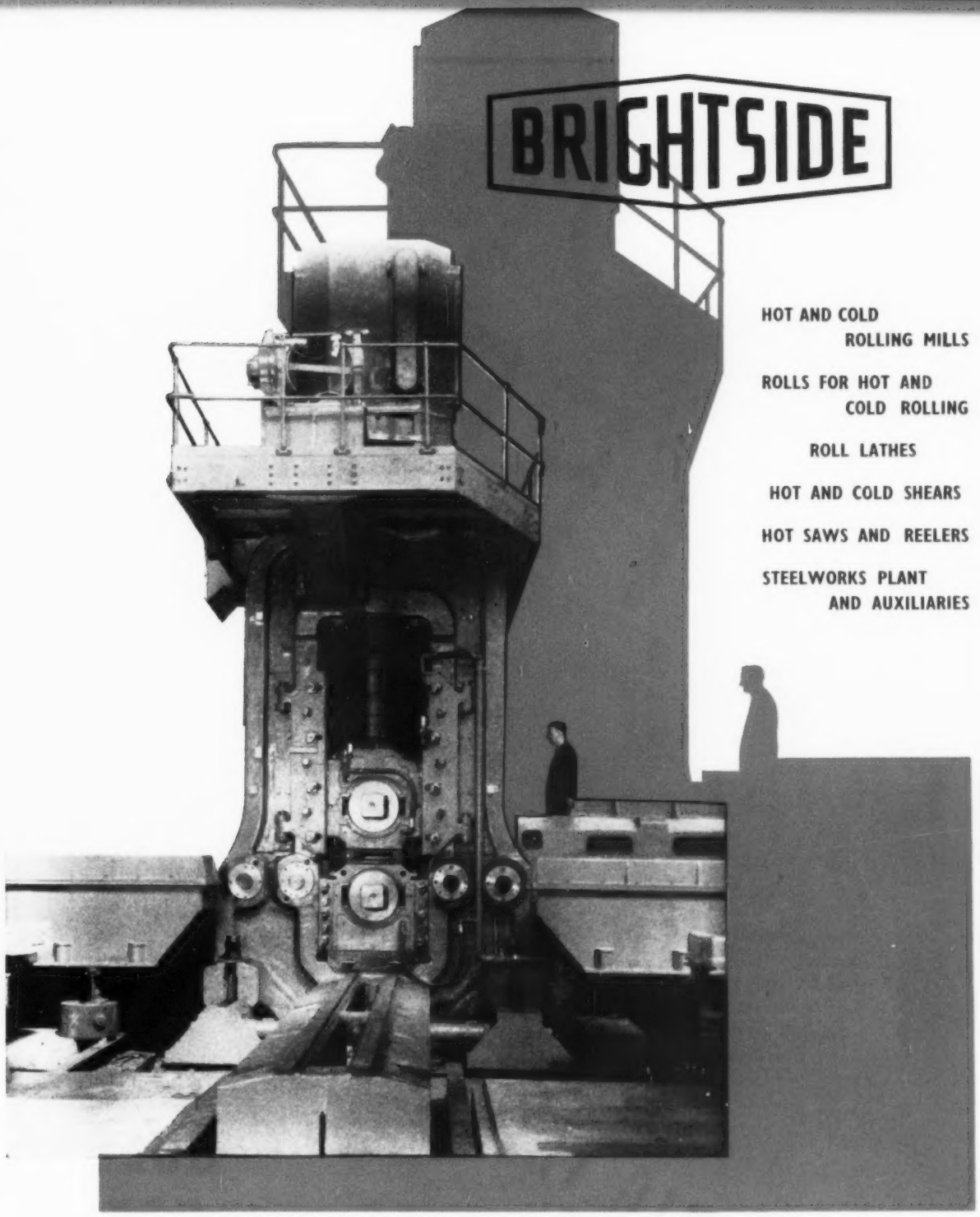

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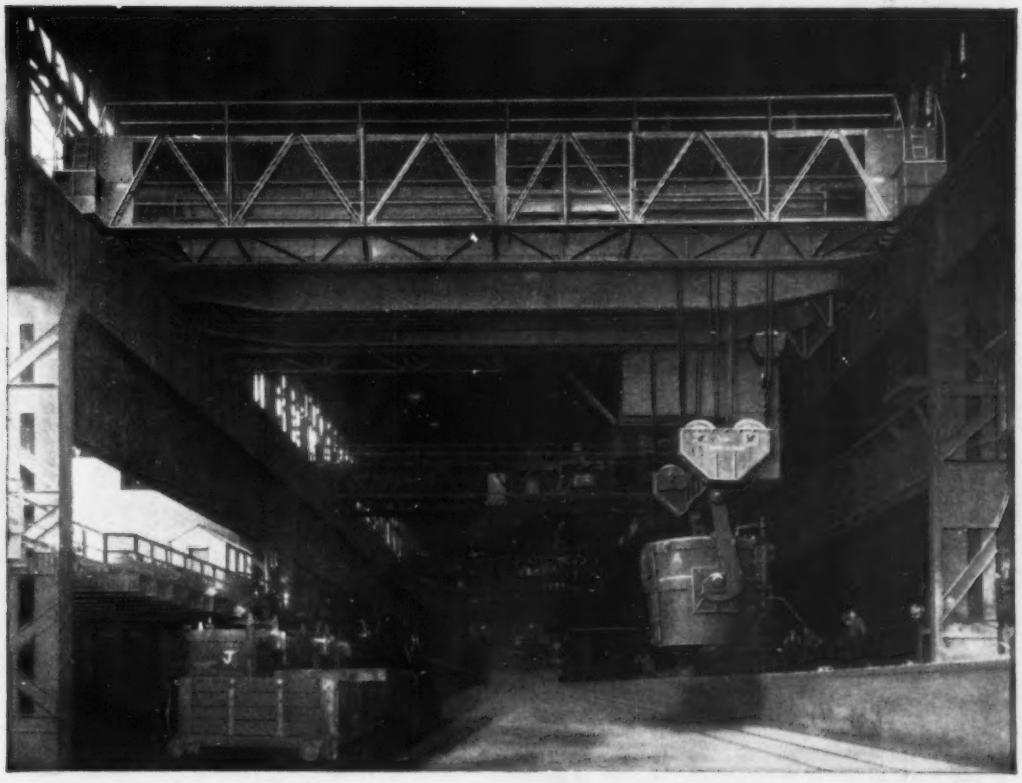

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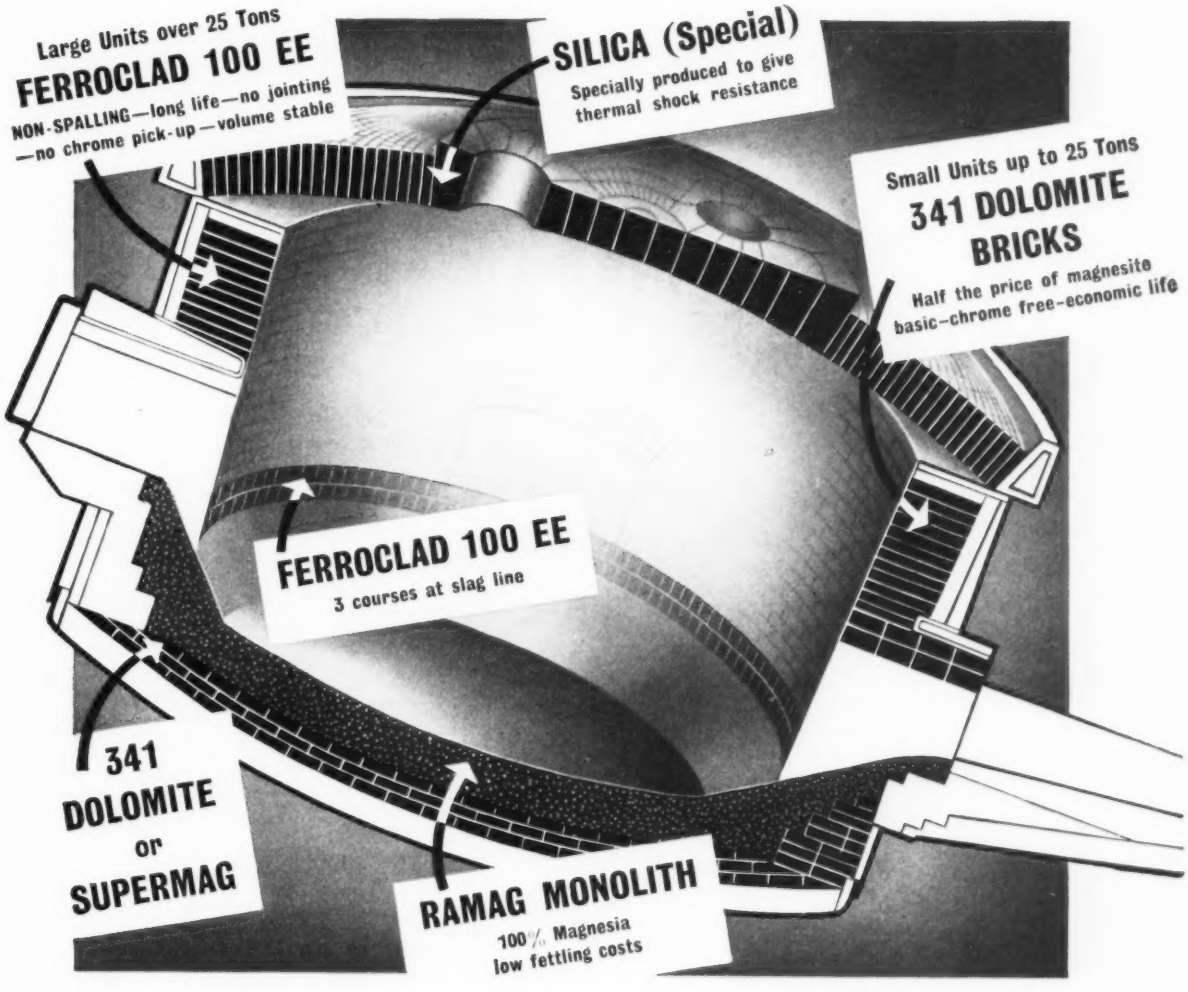

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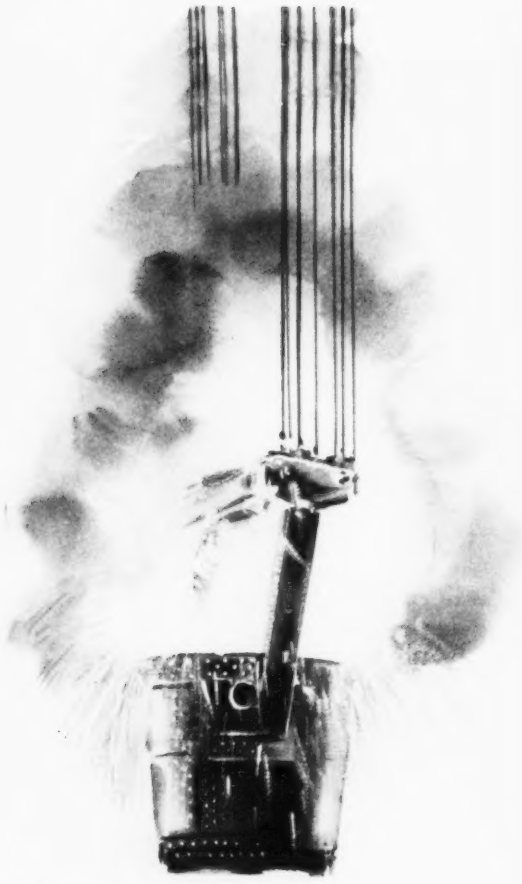

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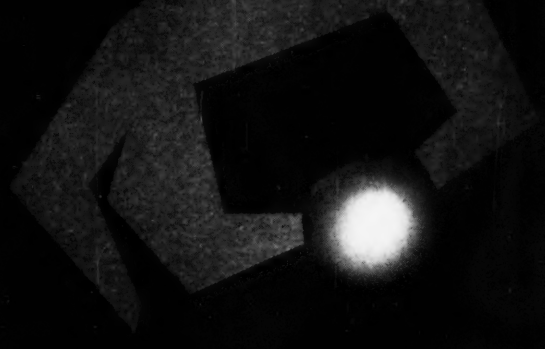

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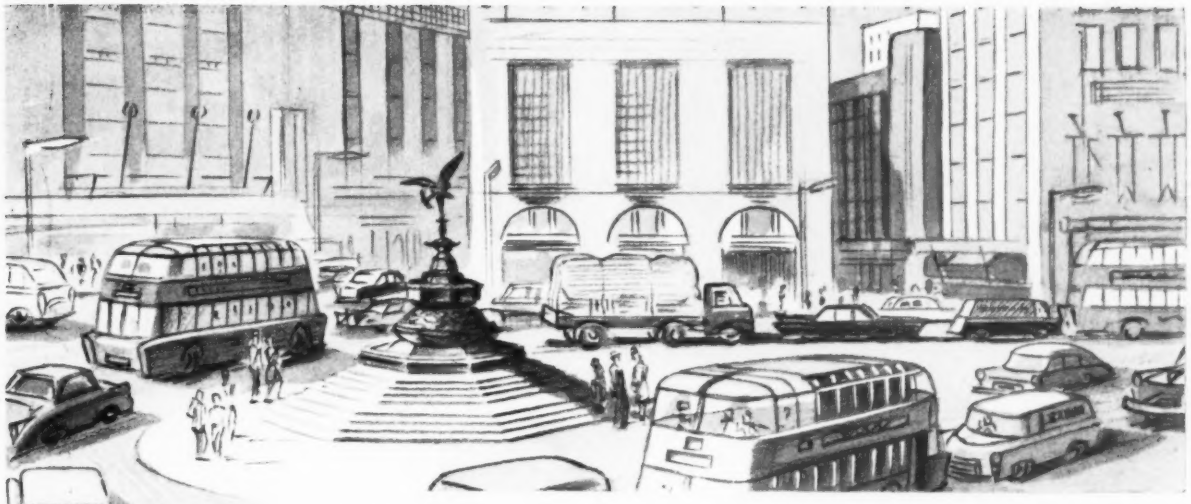

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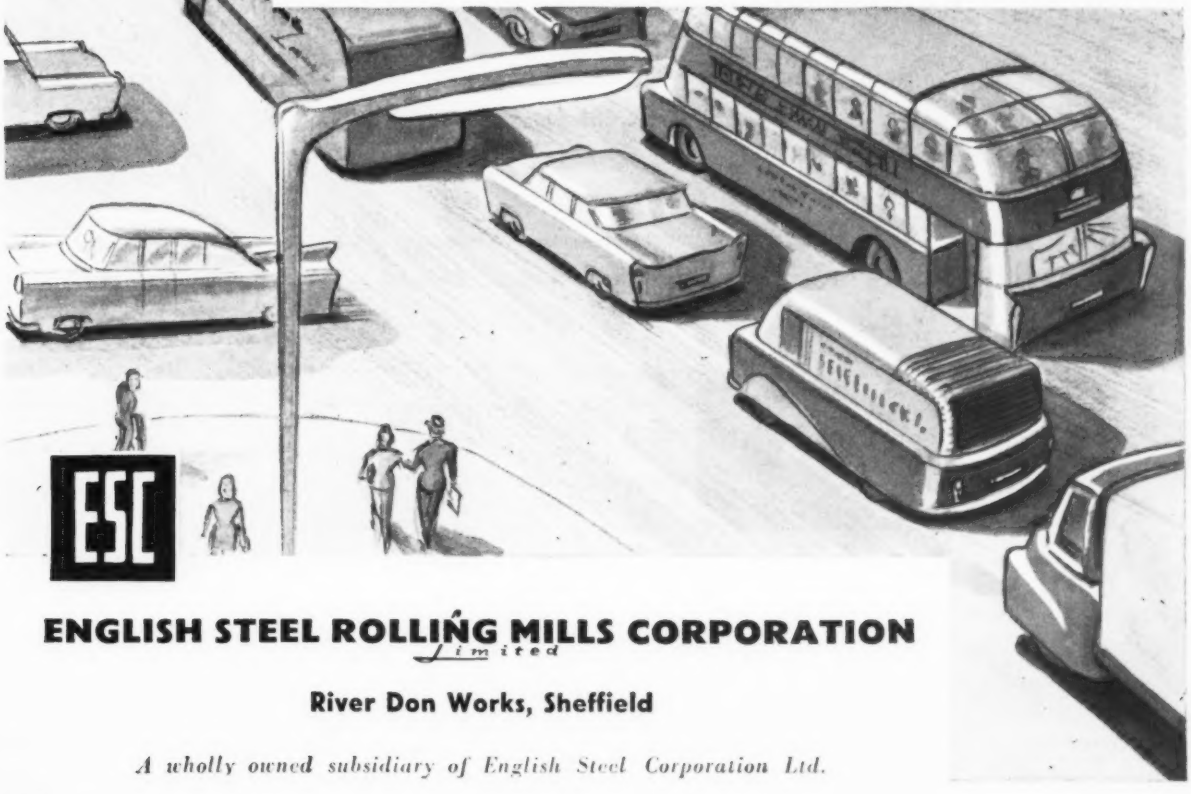

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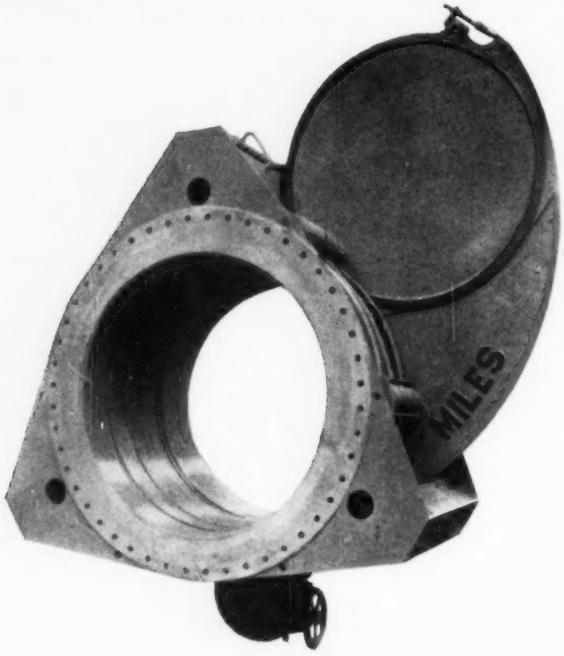

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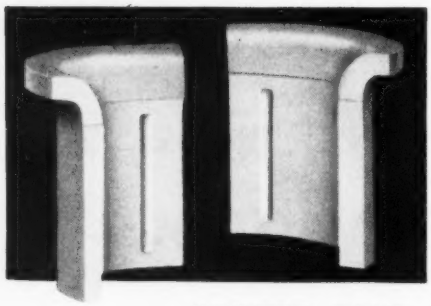

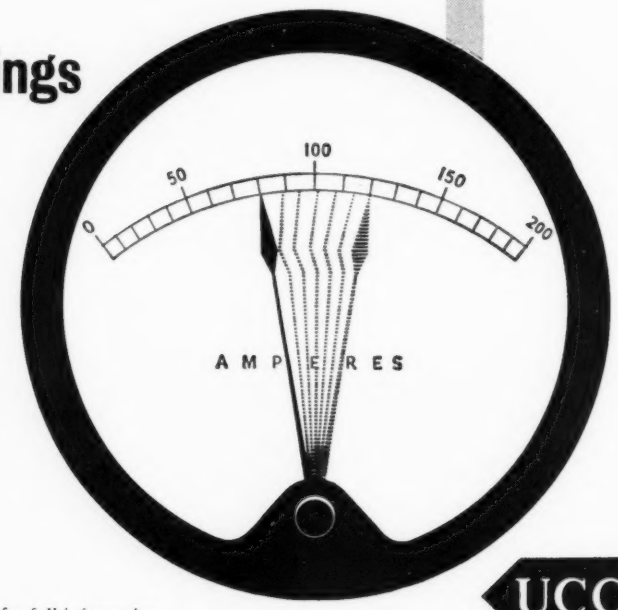

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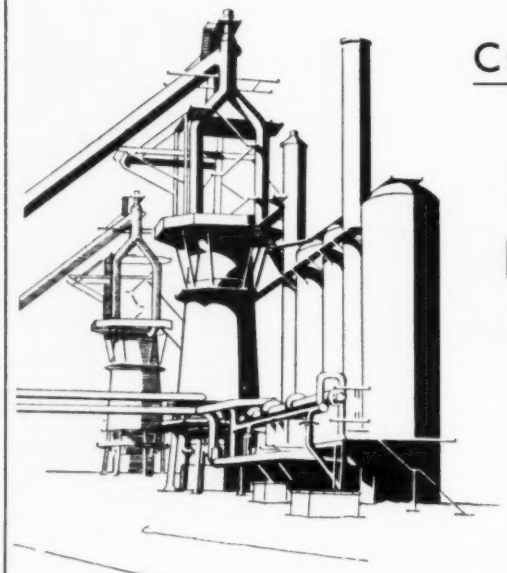

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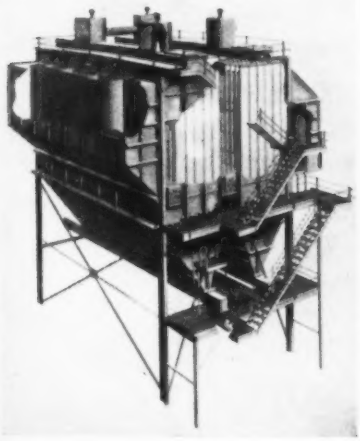

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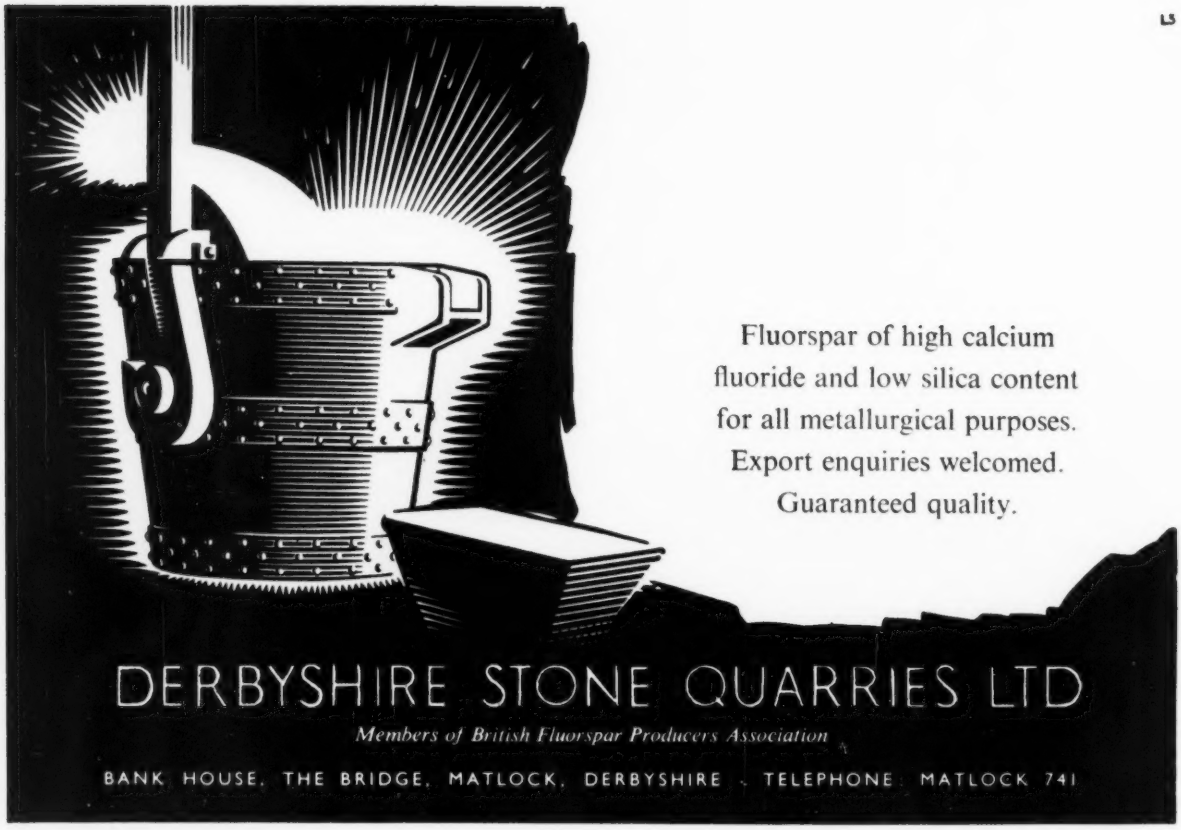

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Two other interesting researches described in the Report concern the corrosion and protection of steel at elevated temperatures up to 350°C, and marine corrosion. As a result of the latter, several reliable anti-corrosive compositions have been formulated, some of which are in use on H.M. ships and the "Queens".

The Report, which consists of 228 octavo pages, illustrated with 20 line and 21 half-tone figures, and bound in cloth with stiff board covers, costs £3 3*s*. 0*d*. (postage 1*s*. 0*d*.), and may be obtained from:

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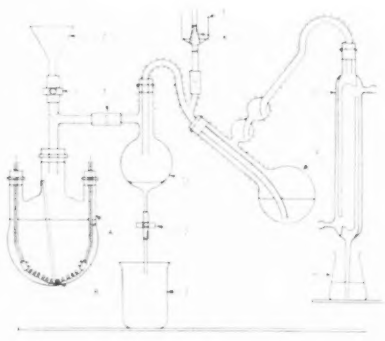
The Determination of Nitrogen in Steel



Great interest has always been shown in the role of nitrogen in determining the properties of ferrous alloys. Reliable and accurate methods are therefore necessary for determining the content of this element in alloys.

The establishment of the reproducibility and accuracy of analytical methods to serve as routine or reference procedures for the many alloys now produced is a major undertaking. It was for this reason that the Nitrogen Group of the Steelmaking Division of the British Iron and Steel Research Association was set up eight years ago. The Report of the Group has now been published as No. 62 in The Iron and Steel Institute's Special Report Series. The information it contains will be of inestimable value to all those interested in this subject.

The Report, which comprises 160 quarto pages and a number of illustrations, is bound in cloth with stiff covers, and costs £1 17*s*. 6*d*. (Members £1 5*s*. 0*d*.). It may be obtained from:—

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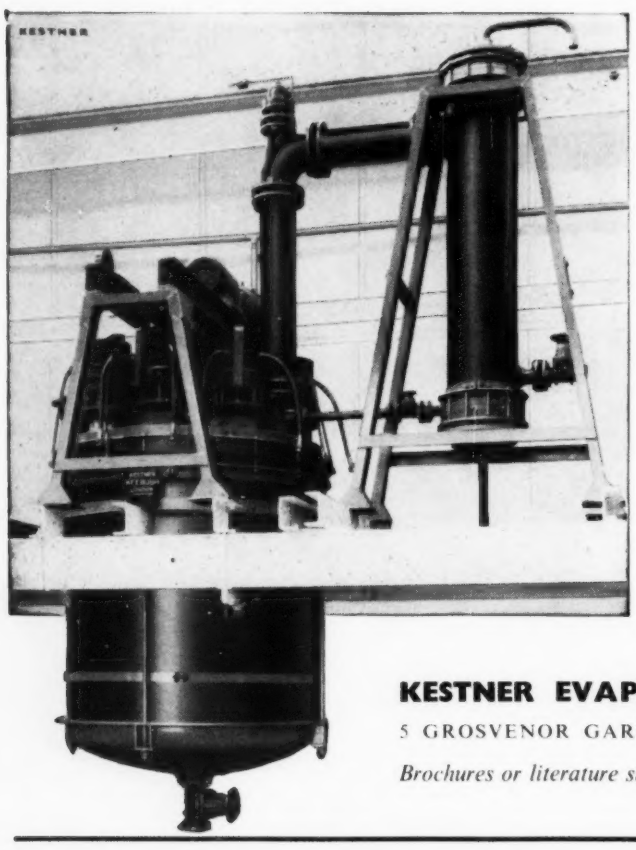

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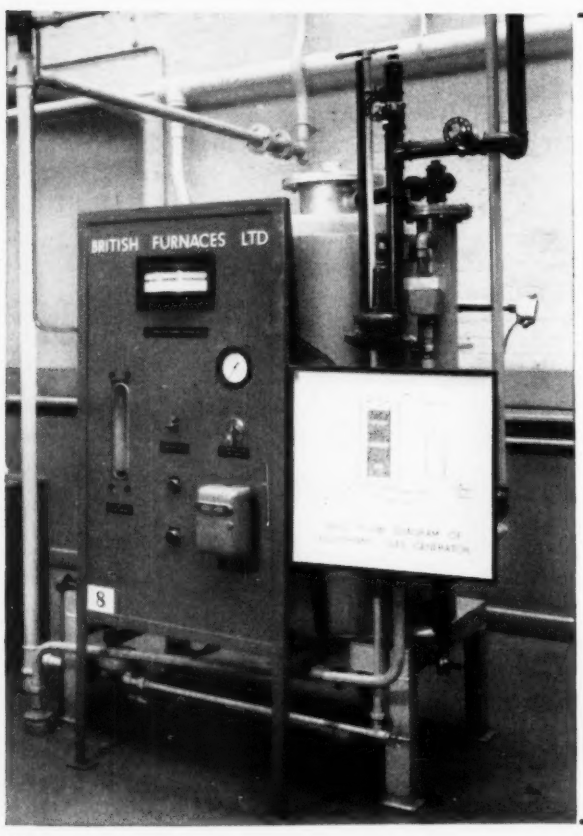

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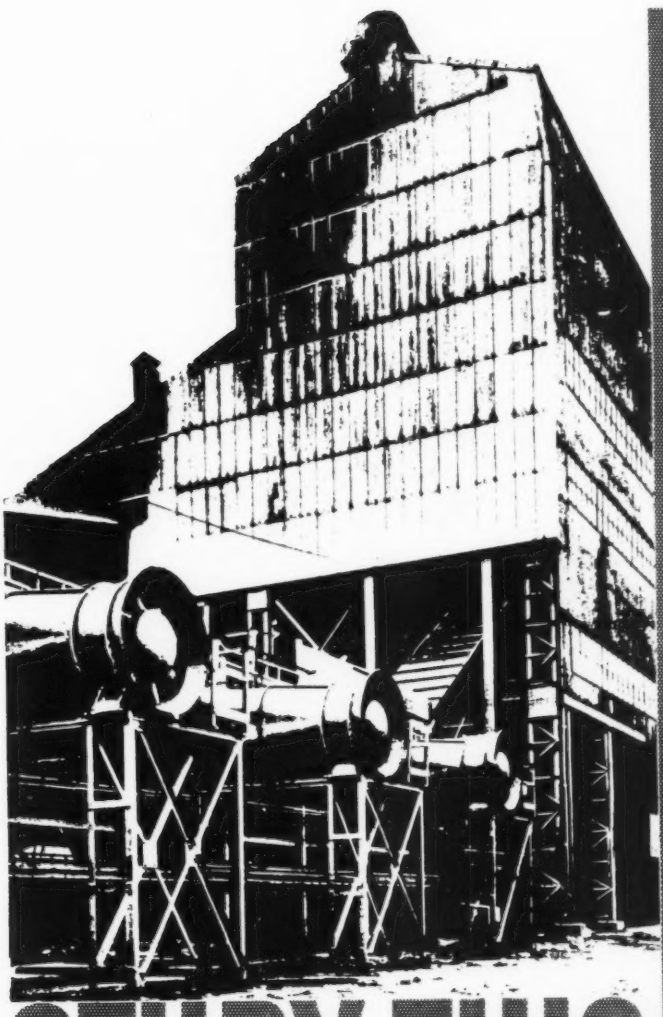

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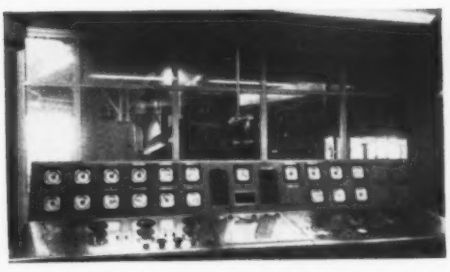

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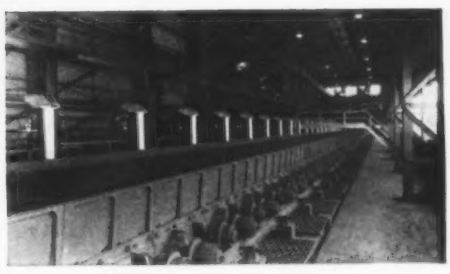

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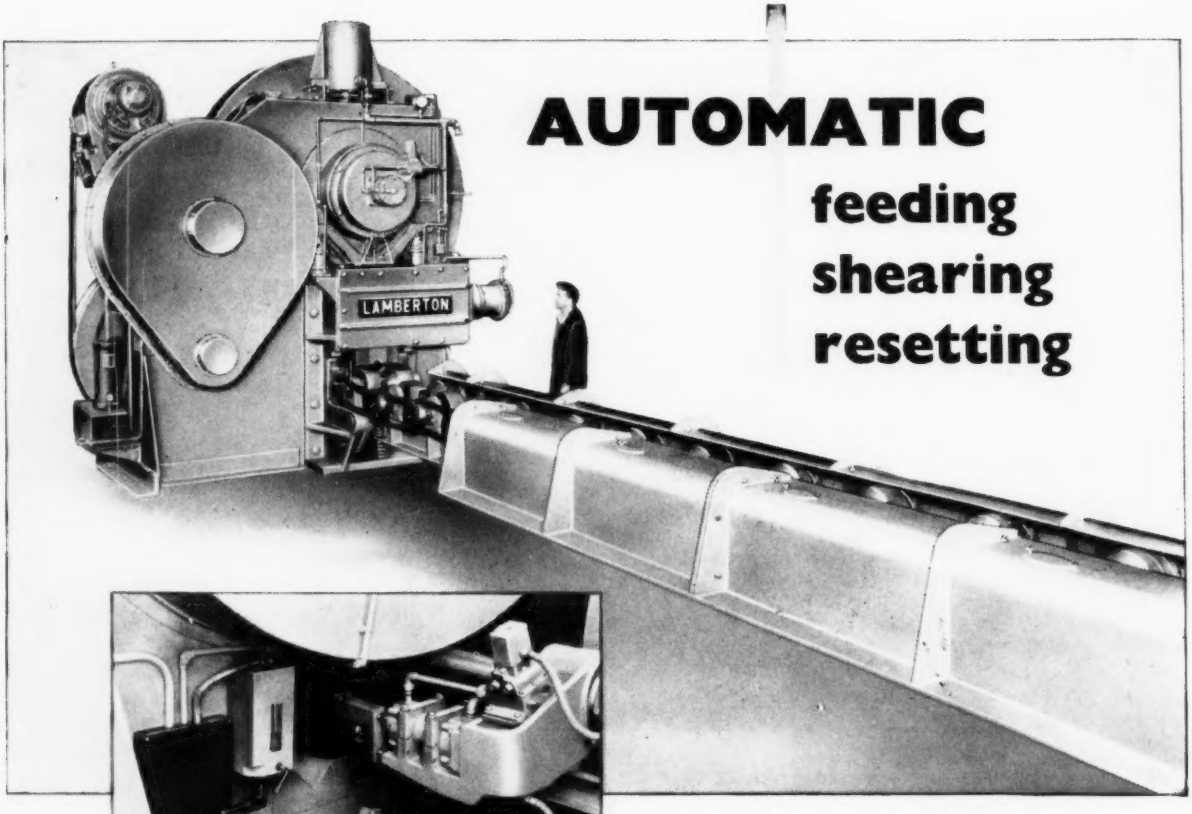

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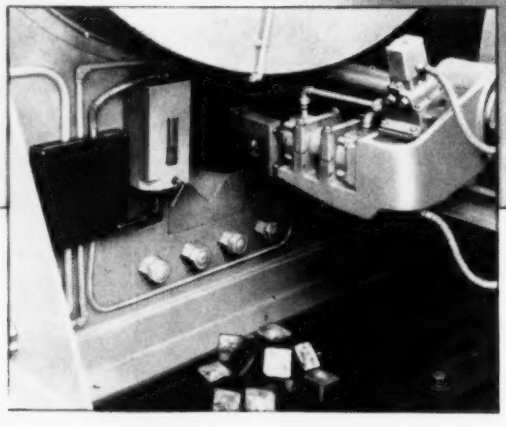

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